BUREAU OF WATER QUALITY
PROGRAM GUIDANCE

Wastewater Policy and Management Team

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Calculating Water Quality-Based Effluent Limitations for Surface Water Discharges

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This document is intended solely as guidance and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

APPROVED:

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Summary

Section 283.13(5), Wis. Stats., requires that effluent limitations be established in permits for point source discharges to surface water to ensure that applicable state water quality standards are met. These types of effluent limitations are protective of water quality and are referred to as water quality-based effluent limits (WQBEL). The WQBEL calculation process completed by the Wisconsin Department of Natural Resources (the department) involves a site-specific evaluation of the discharge receiving water and effluent characteristics and comparison to state water quality standards.

This guidance is intended for use by department staff who are responsible for calculating WQBELs. The document covers how WQBELs are calculated, how staff determine if limits are needed in permits, and how those limits should be expressed in WPDES permits for point source discharges to Wisconsin surface waters.

The following guidance documents also provide information on WQBEL calculation procedures and are used by WQBEL calculation staff. Content from these other guidance documents is not repeated here.

- **Additives and Secondary Values**: Water Quality Review Procedures For Additives, Edition #2
- **Ammonia-nitrogen:** Calculating Ammonia Nitrogen Effluent Limitations for Surface Water Discharges
- **Phosphorus:** Guidance for Implementing Wisconsin's Phosphorus Water Quality Standards for Point Source Discharges
- **Temperature:** Guidance for Implementation of Wisconsin's Thermal Water Quality Standards
- **TMDLs:** TMDL Implementation Guidance for Wastewater
- **Whole Effluent Toxicity:** Whole Effluent Toxicity (WET) Program Guidance Document
- **Variances:** Development and Implementation of Water Quality Standards Variances (DRAFT).

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Abbreviations and Definitions

This list contains the most common abbreviations used in this document as well as a definition of frequently used terms.

Acronym	Term	Definition
	Acute toxicity	The ability of a substance to cause mortality or an adverse effect in an organism which results from a single or short-term exposure to the substance (s. NR 105.03(1), Wis. Adm. Code).
ATC	Acute toxicity criteria	The maximum daily concentration of a substance which ensures adequate protection of sensitive species of aquatic life from the acute toxicity of that substance and will adequately protect the designated fish and aquatic life use of the surface water if not exceeded more than once every 3 years. If the available data indicate that one or more life stages of a particular species are more sensitive to a substance than other life stages of the same species, the ATC shall represent the acute toxicity of the most sensitive life stage. (s. NR 105.03(2), Wis. Adm. Code).
Cs	Background Concentration	Background concentration of the substance within the receiving water (in units of mass per unit volume) as specified in s. NR 106.06(3)(e), Wis. Adm. Code.
BPJ	Best Professional Judgment	
BCC	Bioaccumulative Chemical of Concern	Any substance that has the potential to cause adverse effects which, upon entering the surface waters, accumulates in aquatic organisms by a human health or wildlife bioaccumulation factor greater than 1000.
BOD	Biochemical oxygen demand	Also called biological oxygen demand. A measure of organic strength and a conventional parameter associated with effluent monitoring. Measured and permitted as the oxygen demand exerted in the first five days of the test, the five-day biological oxygen demand (BOD_5).
	Categorical Limits	Technology-based effluent limits which apply to a group of permittees because of similar manufacturing processes, treatment processes, raw materials, or products.
CBOD	Carbonaceous Biochemical Oxygen Demand	The carbon-caused portion of the total biochemical oxygen demand.
	Chronic toxicity	The ability of a substance to cause an adverse effect in an organism which results from exposure to the substance for a time period representing a substantial portion of the natural life expectancy of that organism (s. NR 105.03(14), Wis. Adm. Code).
CTC	Chronic toxicity criteria	The maximum 4−day concentration of a substance which ensures adequate protection of sensitive species of aquatic life from the chronic toxicity of that substance and will adequately protect the designated fish and aquatic use of the surface water if not exceeded more than once every 3 years. (s. NR 105.03(15), Wis. Adm. Code).
CWA	Clean Water Act	Also known as the Federal Water Pollution Control Act.

cfs	cubic feet per second	
CV	Coefficient of Variation	A standardized measure of dispersion of a probability distribution or frequency distribution. CV = the standard deviation divided by the mean.
	Continuous discharge	A facility that discharges 24 hours per day on a year−round basis except for temporary shutdowns for maintenance or other similar activities. (s. NR 205.03(9g), Wis. Adm. Code)
DNR	Wisconsin Department of Natural Resources	
	Design flow	The discharge rate planned at a municipal facility based on the amount of treatment needed and/or the population served at the end of the planning period. May be determined for an annual, monthly, weekly, daily, or hourly basis.
	Dilution	The process whereby the concentration of the discharged substance is reduced because of the lower concentration of that substance in the receiving system; can be expressed as a simple mass balance. Dilution is related to the receiving water flow and the size of the discharge. The lower the available dilution, the greater the potential for toxic effects.
DMR	Discharge Monitoring Report	
DO	Dissolved oxygen	Refers to microscopic bubbles of gaseous oxygen mixed in water and available to aquatic organisms for respiration—a critical process for almost all organisms. Primary sources of DO include the atmosphere and aquatic plants.
Qe	Effluent flows	The flow rate in million gallons per day, that represents the expected effluent discharge rate for limit calculation purposes. For continuous dischargers subject to ch. NR 210, Wis. Adm. Code, Q_e typically equals the annual average design flow rate. For all other dischargers not subject to ch. NR 210, Wis. Adm. Code, Q_e typically equals the maximum average annual flow rate. For seasonal discharges, discharges proportional to stream flow, and other unusual discharge situations, Q_e is determined on a case-by-case basis. (s. NR 106.06(4)(d), Wis. Adm. Code).
EPA	United States Environmental Protection Agency	
f	f	Fraction of the effluent flow that is withdrawn from the receiving water.
FAV	Final acute value	Approximates the concentration equivalent of an LC_{50} or EC_{50}. An adverse effect including mortality will occur to 50 percent of the exposed organisms at this concentration in a given time period. Equal to two times the ATC (s. NR 105.05(2)(f)6, Wis. Adm. Code).
HCC	Human Cancer Criteria	The maximum monthly concentration of a substance which ensures adequate protection of humans from an unreasonable incremental risk of cancer resulting from contact with or ingestion of surface waters.

HHC	Human Health Criteria	Refers to both types of water quality criteria for protective human health: human cancer criteria and human threshold criteria.
HTC	Human Threshold Criteria	The maximum monthly concentration of a substance which ensures adequate protection of humans from adverse effects resulting from contact with or ingestion of surface waters.
	Industrial discharge	Wastewater discharges from industries, any non-municipal wastewater discharge (not subject to ch. NR 210).
IWC	Instream Waste Concentration	An estimate of the proportion of effluent to total volume of water (receiving water + effluent). The IWC equation is provided in ch. NR 106, Wis. Adm. Code.
LOD	Limit of detection	The lowest concentration level that can be determined to be significantly different from a blank for that analytical test method and sample matrix.
LOQ	Limit of quantitation	The concentration of an analyte at which one can state with a degree of confidence for that analytical test method and sample matrix that an analyte is present at a specific concentration on the sample tested.
	Major Municipal discharge/discharger	means a point source discharge with an average daily volume equal to or greater than one million gallons per day of either municipal wastewater from a publicly owned treatment works or of domestic wastewater from a privately owned treatment works (s. NR 200.02(7), Wis. Adm. Code.)
µg/L	Micrograms per liter	
MGD	Million gallons per day	
mg/L	Milligrams per liter	
	Mixing zone	An area where an effluent discharge undergoes initial dilution and is extended to cover the secondary mixing in the ambient waterbody. A mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as acutely toxic conditions are prevented.
	Municipal discharge	Referring to a wastewater treatment facility that treats domestic or mostly residential wastewater. Most commonly (but not always) these facilities are publicly owned treatment works and are subject to ch. NR 210, Wis. Adm. Code.
NBOD	$NBOD_5$	Five-day nitrogenous BOD, the nitrogen-caused portion of the total biochemical oxygen demand from nitrification of ammonia-nitrogen.
	Noncontact cooling water	Water used for cooling which does not come into contact with any raw material, intermediate or finished product, or waste and has been used in heat exchangers, air or refrigeration compressors, or other cooling means where contamination with process waste is not normally expected. (s. NR 205.03(21), Wis. Adm. Code).
	Organoleptic substances	Pertaining to or perceived by a sensory organ. In the context of taste and odor criteria, an organoleptic substance is one that causes objectionable tastes or odors in fish and drinking water.
	P_{99}	The upper 99^{th} percentile of a lognormally distributed dataset as calculated in s. NR 106.05(5), Wis. Adm. Code.
Qs	Stream flow	Stream flow rate used in limit calculations (in units of volume per unit time).
Streamflow Statistics:		

	$1\text{-}Q_{10}$	the lowest one-day flow which occurs once in 10 years
	$7\text{-}Q_2$	the lowest seven-day average flow which occurs once in two years
	$7\text{-}Q_{10}$	the lowest seven-day average flow that occurs once in 10 years
	$30\text{-}Q_5$	the lowest 30-day average flow which occurs once in five years
	$4\text{-}B_3$	a biologically based design flow; the lowest 4-day average flow which occurs once in 3 years.
Stream Classifications:		Fish and aquatic life designated uses as described in s. NR 102.04(3) Wis. Adm. Code:
LAL		Limited aquatic life system pursuant to ch. NR 104, Wis. Adm. Code
LFF		Limited forage fish community pursuant to ch. NR 104, Wis. Adm. Code
WWSF		Warm water sport fish community
WWFF		Warm water forage fish community
CW		Cold water community
	Surface waters	All natural and artificial named and unnamed lakes and all naturally flowing streams within the boundaries of the state, but not including cooling lakes, farm ponds, and facilities constructed for the treatment of wastewaters (s. NR 102.03(7), Wis. Adm. Code).
SWDV	Surface Water Data Viewer	The Surface Water Data Viewer (SWDV) is a DNR data delivery system that provides interactive web-mapping tools for a wide variety of datasets including chemistry (water, sediment), hydrologic, physical and biological (macroinvertebrate, fish) data. Surface Water Data Viewer User Guide Data Layer Inventory
SWIMS	Surface Water Integrated Monitoring System	The Surface Water Integrated Monitoring System (SWIMS) is a DNR system that holds chemistry (water, sediment, fish tissue) data, physical data, biological (macroinvertebrate, aquatic invasive species) data and more. SWIMS is the department repository of monitoring data for Clean Water Act work and is the source of data sharing through the Water Quality Exchange Network.
SWAMP	System for Wastewater Applications, Monitoring and Permits	SWAMP is a database that can generate WPDES permit documents, store facility information, generate monitoring forms, store monitoring data and analyze compliance, track compliance events, and more.
TOC	Taste and Odor Criterion	
TMDL	Total maximum daily load	The maximum quantity of a pollutant(s) that can be discharged into a water quality limited segment over a specified period of time to maintain the applicable water quality standards.
TSS	Total Suspended Solids	
	Toxic substance	A substance or mixture of substances which through sufficient exposure, or ingestion, inhalation or assimilation by an organism, either directly from the environment or indirectly by ingestion through the food chain, will cause death, disease, behavioral or immunological abnormalities, cancer, genetic mutations, or developmental or physiological malfunctions, including

		malfunctions in reproduction or physical deformations, in such organisms or their offspring (s. NR 105.03(27), Wis. Adm. Code).
USGS	United States Geological Survey	
WLA	Wasteload allocation	An individual wasteload allocation is the portion of a total maximum daily load that is allocated to a point sources of pollution.
WQC	Water quality criteria	Numeric or narrative standards for protection of a designated use. Numeric criteria are scientifically derived ambient concentrations developed by the State for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.
	Water quality parameter	One of the indicators available for describing the distinctive quality of water. Those indicators may include hardness, pH, or temperature (s. NR 105.03(30), Wis. Adm. Code).
	Water Quality Standard	The designated beneficial uses of a water segment and the water quality criteria necessary to support those uses.
WQBEL	Water quality-based effluent limits	Limits calculated under s. 283.13(5), Wis. Stats., for toxic and organoleptic substances and whole effluent toxicity. These limitations are necessary to assure attainment and maintenance of surface water quality standards as established in accordance with s. 281.15, Wis. Stats., and as set forth in chs. NR 102 to 106, Wis. Adm. Code.
WET	Whole Effluent Toxicity	The aggregate (total) toxic effect of an effluent as measured directly by a toxicity test.
WC	Wildlife criteria	The maximum monthly concentration of a substance which ensures adequate protection of wildlife from adverse effects resulting from ingestion of surface waters or ingestion of organisms taken from surface waters.
WPDES	Wisconsin Pollutant Discharge Elimination System	The DNR regulates the discharge of pollutants to waters of the state through the Wisconsin Pollutant Discharge Elimination System (WPDES) program. Wastewater permits contain all the monitoring requirements, special reports and compliance schedules appropriate to the facility in question.

Table of Contents

Chapter 1 – Introduction

This chapter provides background on the types of wastewater effluent and receiving water information, administrative codes, and statutes that are needed for the WQBEL calculation process. The sources of information summarized in this chapter generally cover most of the tools needed for WQBEL calculation.

Basic principles and assumptions of WQBELs are as follows:

- WQBELs are calculated in a way to ensure that water quality criteria are attained in surface waters.
- Most WQBELs are calculated using a mass-balance formula that models the effluent mixing with the receiving water, typically assuming that the pollutant behaves conservatively.
- WQBELs are expressed in terms of effluent concentration as state water quality criteria are expressed in terms of concentration. As such, use of effluent concentration measurements allows for direct comparison to permit limits for compliance purposes. Note that limits may also be expressed as mass in some cases.

Section 1.1: Administrative Codes

The following Wisconsin Administrative Codes are most commonly referred to for WQBEL calculating purposes:

Chapter NR 102 defines the designated uses for surface waters and contains narrative standards which prohibit substances in Wisconsin surface waters at concentrations which are toxic or harmful to humans, animals, plants, or other aquatic life. Chapter NR 102 also contains numerical water quality criteria for pH, dissolved oxygen, bacteria, phosphorus, temperature, and preventing objectionable tastes or odors in fish or drinking water.

Chapter NR 104 contains a list of interstate surface waters that do not support full fish and aquatic life uses, called limited forage fish and limited aquatic life waters. The chapter contains the water quality criteria and effluent limitations applicable to discharges to these waters for BOD, pH, dissolved oxygen, and total suspended solids. Chapter NR 104 also lists those waters designated as public water supply and interstate waters.

Chapter NR 105 establishes water quality criteria and methods for developing criteria for toxic and organoleptic substances.

Chapter NR 106 contains procedures for calculating WQBELs for toxic and organoleptic substances, including whole effluent toxicity (WET), mercury, chloride, ammonia, and temperature as well as procedures for determining if and how limits should be included in permits.

Chapter NR 207 establishes implementation procedures for the department's antidegradation and antibacksliding policies.

Chapter NR 212 establishes the procedures, methodologies, and requirements for determining total maximum daily loads (TMDLs) and corresponding WQBELs.

Chapter NR 217 establishes procedures for calculating technology based effluent limits (TBELs) and WQBELs for phosphorus in wastewaters that are discharged to surface waters as well as procedures for determining if and how limits should be expressed in permits.

Section 1.2: Information Gathering

Basic information requirements necessary for limit calculation are summarized below. These items are discussed in more detail in chapters 2 through 4 of this guidance document.

A. Location:

1. Location of the facility and the outfall(s)
2. Stream classification
3. Stream low flow estimates
4. Any nearby dischargers

B. Discharge:

1. Effluent Discharge Rate (in millions of gallons per day or MGD)
2. Source of Water: Groundwater, Receiving water, Public Water Supply, etc.
3. Mixing zone study or Zone of Initial Dilution, if applicable
4. Fraction of the discharge sourced from the receiving water (f)

C. Effluent characterization:

1. Effluent hardness
2. Effluent pH
3. Discharge Monitoring Report (DMR) monitoring data
4. Permit application monitoring data
5. Whole Effluent Toxicity (WET) testing data
6. Any permit violation history

D. Current permit information:

1. Any applicable categorical limitations
2. Limits implemented in the current permit

E. Facility operation information:

1. Facility description
2. Outfall description
3. Treatment type
4. Additives potentially present in discharge
5. Proposed modifications
6. Wastewater characteristics

Section 1.3: Wastewater Discharge Types

The two main types of wastewater dischargers commonly permitted are typically referred to as municipal and industrial. Municipal discharger refers to a treatment plant that treats domestic wastewater subject to ch. NR 210, Wis. Adm. Code, and an industrial discharger refers to all other types of wastewater dischargers not subject to ch. NR 210. The dischargers subject to ch. NR 210 are most often publicly owned treatment works but also include privately owned domestic sewage treatment works that discharge to surface waters (s. NR 210.035, Wis. Adm. Code).

The two main categories are further broken into subcategories that affect the permit application monitoring requirements for different types of dischargers in ch. NR 200, Wis. Adm. Code. Municipal dischargers are subdivided into minor municipal dischargers (typically those with a design flow less than 1.0 MGD) and major municipal dischargers (typically those with a design flow equal to or greater than 1.0 MGD). Industrial dischargers are broken down into primary industrial discharges, secondary industrial discharges, and non-contact cooling water.

Primary industrial discharges include process wastewaters from the following list of industries:

Adhesives and sealants
Aluminum forming
Auto and other laundries
Battery manufacturing
Coal mining
Coil coating
Copper forming
Electric and electronic compounds
Electroplating
Explosives manufacturing
Foundries
Gum and wood chemicals
Inorganic chemicals manufacturing
Iron and steel manufacturing
Leather tanning and finishing
Mechanical products manufacturing
Nonferrous metals manufacturing
Ore mining
Organic chemicals manufacturing
Paint and ink forming
Pesticides
Petroleum refining
Photographic equipment and supplies
Plastic and synthetic materials manufacturing
Plastic processing
Porcelain enameling
Printing and publishing
Pulp, paper and paperboard mills
Rubber processing
Soap and detergent manufacturing
Steam electric power plants
Textile mills
Timber products processing

Chapter 2 – Designated Uses and Water Quality Criteria

A major goal of the Clean Water Act is to protect waters so they are "fishable and swimmable". This national goal is embodied in Wisconsin's water quality standards. Water quality standards consist of three core components: the designated uses of a waterbody, water quality criteria to protect those designated uses, and antidegradation requirements to protect existing uses and high quality/high value waters. In order to calculate WQBELs, the receiving water designated use and the applicable water quality criteria must be determined. This chapter provides an overview of designated uses and associated water quality criteria.

Section 2.1: Designated Uses

Designated uses establish the appropriate water quality goals for a given waterbody. The four main categories of designated use are: fish and aquatic life, recreation, public health and welfare, and wildlife, as shown in Figure 1 and described in detail in the following two pages (s. NR 102.04, Wis. Adm. Code). Several different designated uses will apply to a single surface water. These designations can be thought of as multiple layers of uses that a single waterbody may support.

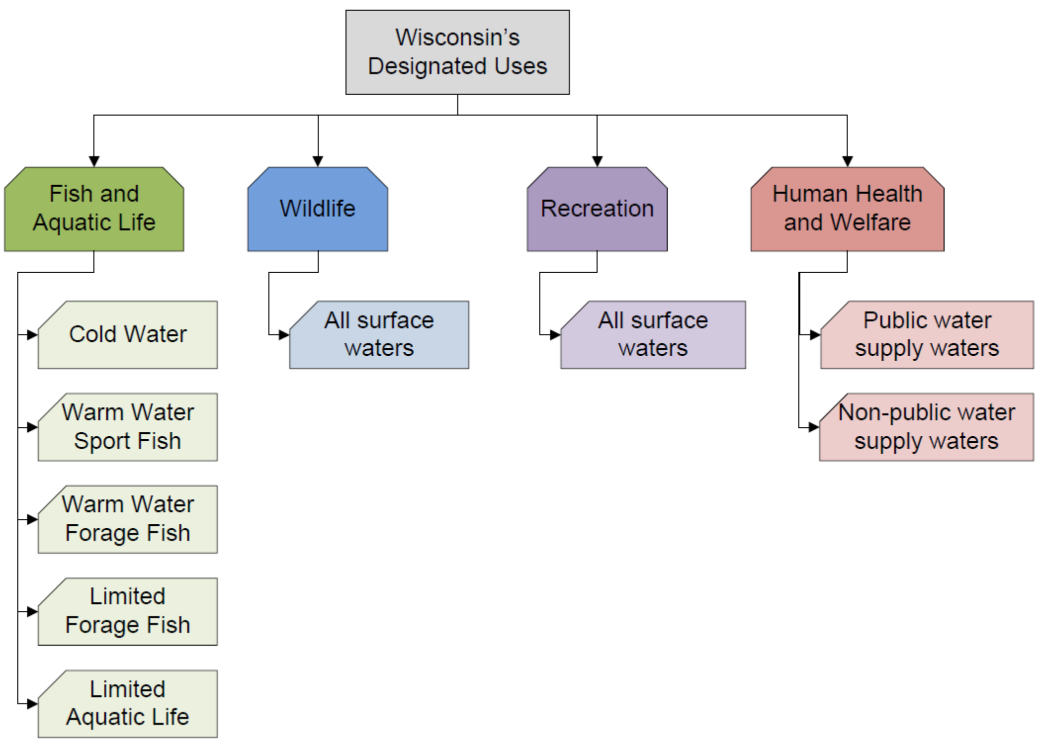


FIGURE 1: "WISCONSIN'S DESIGNATED USE CATEGORIES" FROM THE 2016 GUIDANCE DOCUMENT: *PROCEDURES FOR DERIVING WISCONSIN'S NUMERIC SURFACE WATER QUALITY CRITERIA*

Fish and Aquatic Life Uses: All surface waters shall be suitable for the protection of fish and/or other aquatic life (s. NR 102.04(3), Wis. Adm. Code). Surface waters vary naturally with respect to factors like temperature, flow, habitat, and water chemistry. This variation allows different types of fish and aquatic life communities to be supported. Five subcategories for fish and aquatic life uses are outlined in s. NR 102.04, Wis. Adm. Code.

- Cold water communities: This category includes, but is not restricted to, surface waters identified as trout waters by the department in Wisconsin Trout Streams, publication 6–3600(80). This category is broken into subcategories for ammonia-nitrogen limit calculations, as described in the 2020 guidance document: *Calculating Ammonia Nitrogen Effluent Limitations for Surface Water Discharges*
- Warm water sport fish communities: Capable of supporting a community of warmwater sport fish or serving as their spawning area
- Warm water forage fish communities: Capable of supporting an abundant diverse community of forage fish and other aquatic life
- Limited forage fish communities (aka intermediate surface waters): Waters of limited capacity with naturally poor water quality or habitat which support only a limited community of forage fish and other aquatic life
- Limited Aquatic life (aka marginal surface waters): Waters of severely limited capacity and naturally poor water quality or habitat which support only a limited community of aquatic life.

Wildlife: All surface waters shall be suitable for the protection of wildlife that relies directly on the water to exist or relies on it to provide food for existence. (s. NR 102.04(9), Wis. Adm. Code).

Recreational Use: All surface waters shall be suitable for recreational use in accordance with s. NR 102.04(5), Wis. Adm. Code unless exception(s) described in s. NR 210.06 (3), Wis. Adm. Code apply.

Human Health and Welfare: All surface waters shall be suitable to protect for incidental contact and ingestion by humans. Fish caught for human consumption in surface waters are part of this protected use (ss. NR 102.04(7) and (8), Wis. Adm. Code).

- Public Water Supply: Additionally, some waters are designated for a higher use if they are used as public water supply. The list includes Lake Michigan, Lake Superior, and Lake Winnebago along with other waterbodies.

Additionally, the following designated use layers also apply to some surface waters:

Exceptional or Outstanding Resource Waters: There are no separate water quality criteria for these waters, but special antidegradation requirements apply to them in accordance with s. NR 207.03, Wis. Adm. Code (See Chapter 9).

- Exceptional Resource Waters: Surface waters that provide valuable fisheries, hydrologically or geologically unique features, outstanding recreational opportunities, unique environmental settings, and that are not significantly impacted by human activities

- Outstanding Resource Waters: High quality or ecologically unique waters, such as those within or those reasonably necessary for the protection of waters of National and State Parks and Wildlife refuges.

Great Lakes system waters: Those waters located in the drainage basins of Lake Michigan and Lake Superior.

Table 1 summarizes these designated uses, the associated administrative codes, water quality criteria, and any additional requirements included in administrative code.

<table>
<tr><th colspan="2">Name</th><th>Abbreviation</th><th>Listed In:</th><th>Water Quality Criteria/Requirements</th></tr>
<tr><td rowspan="5">Fish and Aquatic Life</td><td>Cold water communities</td><td>CW</td><td>Trout Handbook*</td><td>s. NR 105 Tables 1 to 6</td></tr>
<tr><td>Warm water sport fish communities</td><td>WWSF</td><td rowspan="2">Default if not otherwise specified</td><td>s. NR 105 Tables 1 to 6</td></tr>
<tr><td>Warm water forage fish communities</td><td>WWFF</td><td>s. NR 105 Tables 1 to 6</td></tr>
<tr><td>Limited forage fish communities</td><td>LFF</td><td>ch. NR 104</td><td>s. NR 105 Tables 1 to 6</td></tr>
<tr><td>Limited aquatic life</td><td>LAL</td><td>ch. NR 104</td><td>s. NR 105 Tables 1 to 6</td></tr>
<tr><td colspan="2">Wildlife</td><td>WC</td><td>All waters</td><td>s. NR 105 Table 7</td></tr>
<tr><td colspan="2">Recreational Use</td><td></td><td>All waters with exceptions in s. NR 210.06 (3)</td><td>Disinfection of treated domestic effluent in May-Sept or an alternative season if deemed appropriate (s. NR 210.06(1)(c))</td></tr>
<tr><td rowspan="2">Human Health</td><td>Human Health and Welfare</td><td></td><td>All waters</td><td>Human Health Criteria in s. NR 105 Tables 8 and 9 (HTC and HCC)</td></tr>
<tr><td>Public Water Supply</td><td>PWS</td><td>Tables 3 through 8 in ss. NR 104.05 to 104.10</td><td>Taste and odor criteria in s. NR 102.14 and separate human health criteria in s. NR 105 table 8 and 9</td></tr>
<tr><td rowspan="2">Tier 3 Waters</td><td>Outstanding Resource Waters</td><td>ORW</td><td>s. NR 102.10</td><td>Special antidegradation requirements</td></tr>
<tr><td>Exceptional Resource Waters</td><td>ERW</td><td>s. NR 102.11</td><td>Special antidegradation requirements</td></tr>
<tr><td colspan="2">Great Lakes System Waters</td><td>GLS</td><td>s. NR 102.12</td><td>- No mixing zones for BCCs
- Use most stringent human health criteria for BCCs
- Special intake credit requirements
- Special antidegradation requirements for BCCs</td></tr>
</table>

TABLE 1: DESIGNATED USES, LIST OF WATERS, AND WATER QUALITY CRITERIA

* includes but not restricted to Wisconsin Trout Streams, publication 6–3600(80)

Section 2.2: Water Quality Criteria

Water quality criteria are adopted to protect the designated uses of a waterbody. Water quality criteria can be numeric (e.g., the maximum pollutant concentration levels allowed in order to maintain designated uses) or narrative (e.g., a statement that describes the desired conditions or the waterbody being free from certain negative conditions). Each designated use class has its own set of pollutants of concern and water quality criteria as shown in Table 2.

Designated Use	Applicable Numeric Criteria
Fish and Aquatic Life	Dissolved oxygen pH Phosphorous Toxic substances Temperature
Recreational Use	Bacteria
Public Health and Welfare	Taste and odor Temperature Toxic substances
Wildlife	Toxic substances

TABLE 2: WISCONSIN'S DESIGNATED USE CATEGORIES AND APPLICABLE NUMERIC CRITERIA FROM THE 2016 GUIDANCE DOCUMENT: *PROCEDURES FOR DERIVING WISCONSIN'S NUMERIC SURFACE WATER QUALITY CRITERIA*

Criteria for Toxics (ch. NR 105, Wis. Adm. Code):

- Fish and Aquatic Life:
  - Acute Toxicity Criteria (ATC): Protect fish and aquatic life from lethality caused by short-term exposure (1-day)
  - Chronic Toxicity Criteria (CTC): Protect fish and aquatic life from sublethal effects (e.g., immobilization, stunted growth, impaired reproduction) caused by long-term exposure (7-days)
- Wildlife Criteria (WC): Protects wildlife from adverse effects resulting from ingestion of surface waters of the state and from ingestion of aquatic organisms taken from the surface waters of the state
- Human Threshold Criteria (HTC) and Human Cancer Criteria (HCC): Protects human health from significant risk through fish consumption, drinking, and recreation. HTC are for substances that cause non-carcinogenic effects and HCC are for substances that cause carcinogenic effects.

  Human health criteria are unique in that they are dependent on both the fish and aquatic life use and whether the water is designated as a public drinking water supply. This is because of differences in water consumption, fish consumption and the fish species expected in the different classifications.

For more information related to the derivation of water quality criteria, refer to the 2016 guidance, *Procedures for Deriving Wisconsin's Numeric Surface Water Quality Criteria*.

Section 2.3: Recreational Criteria and Disinfection

By default, all surface waters are considered appropriate for recreational use (no distinction between full immersion and incidental contact, s. NR 102.04(5), Wis. Adm. Code). Generally, discharges of municipal or domestic wastewater are required to disinfect effluent in the period of May through September prior to discharge. The possible exceptions are discussed in this section:

Adjusted Disinfection Seasons:
Effluent disinfection is typically required in May through September for discharges to recreational waters, but a different disinfection season may be required depending on certain circumstances. In accordance with s. NR 210.06(1), Wis. Adm. Code, there are two reasons for an adjusted disinfection season:

1. Year-round disinfection shall be required in public drinking water supplies.
2. The disinfection season may be adjusted to protect human and animal life (where it's known that recreational activities occur outside of May through September or affected wildlife may be present.)

The second reason stated above could result in a shorter or longer disinfection season. For example, a disinfection period of June through September might be appropriate at a site in the northern part of the state as a result of extended time periods of ice cover. Alternatively, an extended recreation period might be appropriate in an area where it's known that some recreational activities occur outside the months of May through September.

Disinfection Exemptions:
In accordance with s. NR 102.04(5)(b), Wis. Adm. Code, the department may determine that wastewater disinfection is not required to protect recreational uses in some cases. The procedures in s. NR 210.06(3), Wis. Adm. Code, specify that the following factors should be evaluated as part of determining the appropriateness of exempting disinfection:

1. Proximity to beaches or other recreational areas
2. Proximity to drinking water intakes
3. Proximity to wetlands with waterfowl subject to disease
4. Effluent quality
5. Dilution and mixing with receiving water
6. Bacteria levels in the surrounding area
7. Receiving water and downstream classifications
8. Treatment system detention time
9. Any other factors related to risk to human or animal health

Additionally, s. NR 210.06(3)(h), Wis. Adm. Code, specifies that when treatment system detention time is equal to or greater than 180 days, non-disinfected effluent will not pose a risk to human and animal health. This factor is a commonly cited reason for determinations that no disinfection is needed.

For certain waters, a determination may be made that there is no risk to human health because the water is not suited for recreational use. This determination may be based on factors like the size of the stream (too narrow for bathing or kayaking, etc.) or lack of access to the waterbody.

Section 2.4: Point of Standards Application and Downstream Impacts

In WQBEL calculation, it is important to consider the designated uses of the receiving water at the outfall location as well as any downstream designated uses that may be affected by the discharge. WQBELs for the downstream use must be evaluated to ensure that the downstream water quality criteria are met whenever information to make the determination is available (s. NR 106.06(1)(b), Wis. Adm. Code). If a pollutant does not dissipate, precipitate, or otherwise decay completely prior to reaching the point of a receiving water classification change, a limit may be required in the permit to ensure that the downstream water is protected. The classification change may occur at the confluence of the receiving water with a different downstream waterbody. Classification changes can also occur within the same waterbody at a distance downstream where changes in the hydrology and habitat allow attainment of a different designated use.

Another possible scenario is where effluent is not directly discharged to a water of the state. For example, some facilities discharge effluent to on-site stormwater ponds. When these ponds are completely contained on the WPDES permit holder’s property, they are not considered waters of the state and water quality criteria do not apply directly to them. The point of standards would be at the point where the stormwater pond overflows to a surface water that is considered a water of the state.

When effluent passes through different designated uses, there may be multiple points of standards to be considered. WQBELs should be calculated to ensure that the water quality criteria for each designated use are met at each respective point of standards application. When appropriate, the limit calculation may consider pollutant decay that will occur as the effluent travels downstream. This kind of evaluation is most often applied for ammonia-nitrogen, because it is not a fully conservative pollutant.

Chapter 3 – Using Criteria to Calculate Limits

WQBELs are calculated by modeling steady state conditions using a mass balance equation. The main objective of the WQBEL calculation procedures in chs. NR 106 and 217, Wis. Adm. Code, is to set a limit for the effluent concentration (Ce) that will ensure that water quality criteria (WQC) are met in the receiving water.

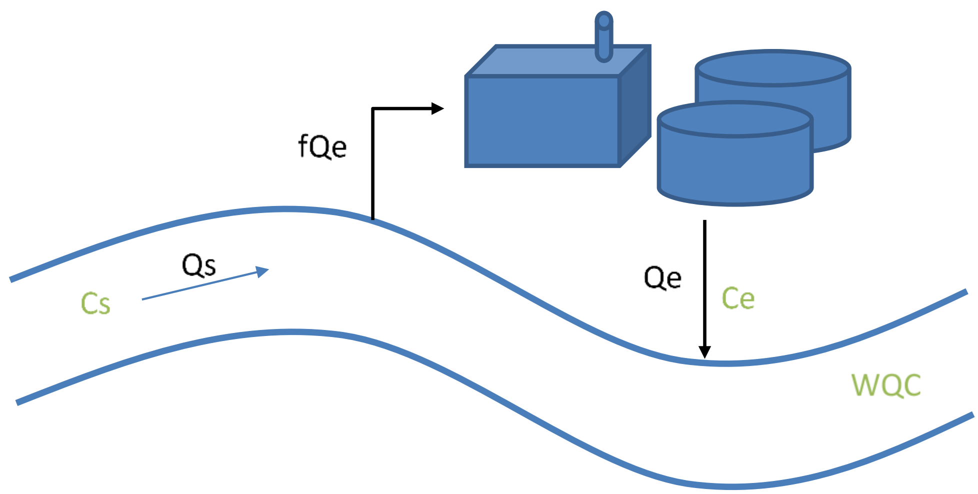


FIGURE 2: WASTEWATER DISCHARGE WITH MASS BALANCE EQUATION VARIABLES

The following general equations are used to calculate limits for most pollutants in accordance with ss. NR 106.06(3)(b) and (4)(b), Wis. Adm. Code. The same equations are repeated for ammonia-nitrogen (ss. NR 106.32(2)(e) and (3)(b), Wis. Adm. Code) and the same unidirectional flow equation is used for phosphorus (s. NR 217.11(2)(a), Wis. Adm. Code).

The Mass Balance Equation for waters with unidirectional flow:

$$WQBEL = \frac{WQC \times (Q_s + [1-f]Q_e) - (Q_s - fQ_e) \times C_s}{Q_e}$$

For waters with no unidirectional flow, a 10:1 mixing zone is assumed unless an alternative mixing zone is demonstrated to be more appropriate, according to s. NR 106.06(4)(b)2., Wis. Adm. Code:

$$WQBEL = 11WQC - 10C_s$$

Where:

WQC = Water quality criteria
Q_s = Receiving water design flow
Q_e = Effluent flow rate
f = Fraction of the effluent flow that is withdrawn from the receiving water
C_s = Background concentration of the substance

For limits based on acute criteria, limits may also be based on an additional equation. Acute limits are calculated using both the mass balance equation above and the final acute value (FAV) approach from s. NR 105.05(2)(f)6, Wis. Adm. Code:

$$WQBEL = FAV = 2 \times ATC$$

The more restrictive of the two limits shall be used in accordance with s. NR 106.06(3)(b)3, Wis. Adm. Code (unless a zone of initial dilution applies, s. NR 106.06(3)(c), Wis. Adm. Code).

The values selected for receiving water design flow, effluent flow rate, and background concentration vary based on the type of discharge and the criteria being considered. Selecting appropriate values for these inputs is discussed in Sections 3.1 through 3.3.

Exceptions to the above mass balance equations:

- Phosphorus in waters without unidirectional flow: For phosphorus dischargers to waters with no unidirectional flow, a 10:1 mixing zone is not assumed. Limits for discharges to inland lakes are set equal to the applicable water quality criteria, according to s. NR 217.13(3), Wis. Adm. Code. Discharges directly to the Great Lakes currently have an interim limit until a nearshore or whole lake model can be developed, according to s. NR 217.13(4), Wis. Adm. Code.

- Temperature: Separate equations for temperature limits are given in s. NR 106.55(7)(b), Wis. Adm. Code. These follow the same general mass balance method as the equation above but account for the unique nature of heat as a pollutant.

- Bacteria and pH: No dilution is considered in the WQBELs for these pollutants. Limits for these compounds are simply set equal to the applicable criteria or categorical limit.

Section 3.1: Stream Flows

To ensure that limitations are protective of water quality under all conditions, conservative values are selected for the receiving water flows (Qs). For most pollutants, this means an estimate of a low flow period where a lower than usual amount of dilutions will be available.

$$WQBEL = \frac{WQC \times (\boldsymbol{Q_s} + [1-f]Q_e) - (\boldsymbol{Q_s} - fQ_e) \times C_s}{Q_e}$$

Sections NR 106.06(4)(c) and (3)(bm), Wis. Adm. Code, specifies the receiving stream flows to be used to calculate effluent limits based on acute, chronic, wildlife, human cancer, human threshold, taste and odor criteria and associated secondary values.

- Acute criteria – 100% of 1-Q_{10} or 80% of the 7-Q_{10} (s. NR 106.06(3)(bm))
- Chronic criteria – 25% of 7-Q_{10} or 4-B_3 (s. NR 106.06(4)(c)5)
- Wildlife criteria – 100% of the 90-Q_{10} or 85% of the 7-Q_2 (s. NR 106.06(4)(c)8)

- Human Threshold and Human Cancer – 25% of the Harmonic Mean flow (s. NR 106.06(4)(c)10)
- Taste and Odor – 100% of the Mean Annual Flow (s. NR 106.06(4)(c)11)

Alternative stream flows are also used for other pollutants:

- Phosphorus – 100% of 7-Q_2 or 30-Q_3 (s. NR 217.11(2)(b))
- Temperature – 25% of 7-Q_{10} or 4-B_3 (s. NR 106.55(6)(b))
- Ammonia-nitrogen (chronic) – Weekly: 7-Q_{10} or 4-B_3 and Monthly: 30-Q_5 or 85% of the 7-Q_2 with variable percent mixing (s. NR 106.32(3)(c))

It should be noted that several types of limits allow for use of a biological based flow, such as a 4-B_3. This flow is not the same as a 4-Q_3. The biological flow is the flow which prevents an excursion from the water quality criteria for a duration of 4 days and a frequency of less than once every 3 years (4−day, 3−year biological flow).

The percent mixings listed above may not always apply. An alternate percent mixing may be used in limit calculation if a mixing zone study (for chronic limits) or a zone of initial dilution (for acute limits) has been completed in accordance with ss. NR 106.06(3)(c), (4)(b)2, and (4)(c), Wis. Adm. Code. It should be noted that some mixing zone studies are only for particular pollutants and may not be applicable for others.

If the facility has an approved zone of initial dilution (ZID) study, the ZID is applied through a ratio of effluent to receiving water, similar to how limits are calculated for lake discharges. This ratio is expressed differently depending on the ZID study. Some studies provide a ratio as "receiving flow: effluent flow" and others provide a ratio of "[receiving flow + effluent flow]: effluent flow". The calculation of the acute mixing zone for WET uses the later expression of ZID ratio. The limit calculator should check the study for how the ratio has been expressed and adjust the calculation accordingly.

The rest of this section provides information on the sources for obtaining these flows. Appendix A provides possible methods for estimating low flows depending on the amount of site-specific information that is available.

Low Flow Estimates

As noted above, conservative low flow values are the most frequently used in WQBEL calculations. The most commonly used low flow, the 7-Q_{10}, refers to the minimum expected 7-day average flow that would occur over a 10-year period. Other low flows used in WQBEL calculations may include the 7-Q_2, 90-Q_{10}, 30-Q_3, 30-Q_5, and 1-Q_{10}.

Typically, existing low flow estimates from USGS are used in WQBEL calculations. These most often consist of annual 7-Q_{10} and 7-Q_2 flows. Other necessary low flows may be estimated based off of these low flows (ss. NR 106.06(3)(bm) and (4)(c) Wis. Adm. Code).

Updating Low Flows

In some situations, it may be appropriate to update low flow estimates instead of carrying over previous USGS-provided flows. Due to changes in agricultural practices, low flows have generally increased over time (Gerbert et. al. 2016). Climate change has also likely had an impact on flows. If low flows are updated and a higher estimate is obtained, this may result in the calculation of less stringent WQBELs. Increasing or removing any currently effective permit limit requires a successful antidegradation and antibacksliding demonstration prior to implementing the revised calculated WQBEL. More detail on antidegradation and antibacksliding are provided in Chapter 9.

The following factors should be considered before taking efforts to update low flow estimates:

1. What limits would be potentially affected by updated low flows?
2. What is the likelihood of the permittee successfully demonstrating that antidegradation and antibacksliding requirements are met?
3. What flow information is already available and what information could be obtained?
    a. Active stream gauge on the receiving water in vicinity of discharge (with ≥10 years flow record)
    b. Permittee willingness/ability to contract with USGS
    c. Permittee willingness/ability to take base flow measurements on-site

In situations when it is appropriate to update low flows, there are three main methods that may be used to calculate receiving water low flows for use in WQBEL evaluations: (1) direct calculation using empirical data from continuous gauge sites, (2) regression analysis using base flow measurements, and (3) multiple regression analysis for ungauged or minimally gauged sites. The methods described below are ordered from most accurate to least accurate. For more details on these methods, see Appendix A.

If an active stream gauge is located on the receiving water at a reasonable distance from the point of discharge, low flows may be calculated directly from the gauge data using Method (1). If the stream gauge is not located directly upstream of the discharge, it may be necessary to use the rule of proportions to adjust these flows (see below).

If there is no active stream gauge, updated low flow estimates would use some variation of method (2). If the permittee is willing to take at least three base flow measurements, these can be provided to USGS to create a more accurate low flow estimate. If base flow measurements are not available, the low flow calculation will be based on estimated base flows instead. To request updated low flows or monthly low flows, permittees should contact hydrologist Robert Waschbusch at USGS (rjwaschb@usgs.gov).

Use of method (3) flows for WQBEL calculation should be avoided whenever possible given comparison of flows calculated with the multiple regression equations and site-specific low flows provided by USGS has shown that these equations generally over-estimate low flows. These equations should generally be reserved for calculating limits for protection of downstream waters where another USGS low flow estimate does not already exist.

Monthly Low Flows

Low flow estimates are typically provided on an annual basis using data from the whole year, but specific low flows can also be calculated for each month of the year. Because the period for each low flow estimate is much narrower, the low flow estimates for monthly low flows tend to be significantly higher than annual low flow estimates.

If a facility is interested in obtaining a monthly low flow estimate for their receiving water, they can contract with USGS to obtain updated monthly 7-Q_{10} and 7-Q_2 flows. Monthly low flows are most commonly used when parameters are known to vary seasonally in both the effluent and the receiving water. This is the case for temperature limits where the criteria also differ for each month. Monthly low flows may also be used for ammonia-nitrogen and BOD_5 WQBEL calculations, since the criteria or resulting limits are dependent on receiving water temperatures which are highly variable throughout the year. These parameters also commonly have monthly or seasonal limits because they're known to vary seasonally in both the effluent and receiving water.

For other pollutants including toxics other than ammonia-nitrogen, the department only uses updated annual low flow estimates for limit calculation. Due to the relatively high uncertainty and sometimes dramatic increases seen in updated monthly low flow estimates, using those estimates in limit calculations can greatly reduce the safety factor which depends on using conservative estimates. In cases where low flows increase dramatically, it's reasonable to expect that the flows may lower again in the future, which leads to a "moving target" situation where limits increase or decrease at each reissuance, causing planning difficulties for the facility.

Use of monthly low flows can also be problematic if there is limited effluent data available to determine reasonable potential or compliance. If monthly low flows are used in limit calculation, the pollutant should be monitored at least once per month to ensure that the limits are protective year-round. This is not an issue for temperature, ammonia-nitrogen, and BOD_5 since these are all measured more than once per month at most municipal facilities. Other toxics are typically not monitored as frequently, and additional monitoring can be quite expensive for some toxics.

Also, alternative mixing zone percentages from mixing zone studies should generally not be used in combination with monthly low flows. An exception to this approach may be acceptable if the department mixing zone expert determines that the mixing zone study uses data from multiple months of the year which adequately cover the variability of flow conditions expected throughout the year.

Rule of Proportions

When gauge data is available for a stream, but it is located far from the outfall, EPA recommends using the Rule of Proportions (explained in the EPA *Low Flow Statistics Tools: A How-To Handbook for NPDES Permit Writers*):

$$Q_{outfall} = Q_{gauge} \times \frac{A_{outfall}}{A_{gauge}}$$

Where:

$Q_{outfall}$ = Low flow statistic at outfall location

Q_{gauge} = Low flow statistic at gauge location

$A_{outfall}$ = Area draining to outfall

A_{gauge} = Area draining to gauge

Before using this approach, consideration should be given to whether flows at the gauged site are representative enough to be compared to the outfall location. According to the handbook, "In general, the rule of proportions method for adjusting low flow values will provide more accurate results when the two drainage areas are roughly the same size. According to Hortness (2006), a good rule of thumb is to apply this method when the ratio between the $A_{outfall}/A_{gauge}$ is around 0.5 to 1.5."

Consideration should also be given to any tributaries that meet with the receiving water in between the gauge station and the outfall. If any tributaries are present, an estimate of the tributary flow should also be determined and accounted for in the flow estimate.

Harmonic Mean Flow

U.S. EPA *Technical Support Document for Water Quality-Based Toxics Control* (March 1991, EPA/505/2-90-001, pgs. 88-89) provides multiple methods for estimating a harmonic mean when continuous gauge data is not available. These methods were compared using Wisconsin stream gauge data from 1968 to 1988 and found that the following equation provided the most accurate estimate:

$$Harmonic\ Mean\ Flow = 1.2 \times Q_{avg}{}^{0.5} \times 7Q_{10}{}^{0.5}$$

A default harmonic mean flow using this equation is recommended when a site-specific harmonic mean has not already been calculated. If a limit is triggered using this estimate, an effort should be made to calculate a site-specific harmonic mean flow estimate if possible. If continuous stream flow data is available, a harmonic mean can be calculated from the data downloaded from USGS (nwis.waterdata.usgs.gov). Alternatively, the permittee may choose to contact the USGS to provide a more detailed flow estimate at their own cost.

Annual Mean Streamflow (Q_{avg})

If stream gauge data for the receiving water is available, the average of the measured flow rates should be used. Where flow data is not available, an estimate of the annual mean streamflow is available in SWDV and the WPDES viewer. These predicted flows come from the Wisconsin Stream Natural Community Model.

Other Considerations:

- Seiche Effects: Seiche effects occur when wind conditions on a lake or large body of water cause standing waves of water and slightly uneven lake levels. Streams with a mouth located on a lake may be influenced by seiche effects and may experience days of zero flow or upstream/reversed flow**.** These days would be recorded by USGS as a zero or negative flow rate. A harmonic mean calculation cannot include these values. Since the harmonic mean is used to protect against long-term human health effects, zero and negative flow values from short-term seiche conditions should be excluded in calculating a harmonic mean. Negative values should be excluded from all other stream flow calculations as well.

- Upstream Dam Regulation: Similarly, dams located upstream of a site may cause zero (or near zero) streamflow during short periods for dam maintenance. These flow values should be screened out before calculation of a harmonic mean flow. Some dams are required by the Federal Energy Regulatory Commission (FERC) to maintain a minimum flow through rate. In these cases, the stream flow distribution would have a "cut-off" at that minimum flow, so the commonly used statistical techniques would not be useful. If the receiving water is directly influenced by a dam with controlled operations, the low flows may be based on dam operations.

Section 3.2: Effluent Flow Rates

In the mass balance equation used to calculate limits as explained on page 19, Qe or effluent flow rate will differ depending on the type of facility and limit type.

$$WQBEL = \frac{WQC \times (Q_s + [1 - f]\boldsymbol{Q_e}) - (Q_s - f\boldsymbol{Q_e}) \times C_s}{\boldsymbol{Q_e}}$$

Effluent flow rates to be used in limit calculations are defined in ss. NR 106.06(4)(d) and NR 106.07(2), Wis. Adm. Code, and summarized in Table 3 below.

	Concentration Limits (s. NR 106.06(4)(d))		Mass Limits (s. NR 106.07(2))	
	Municipal	**Industrial**	**Municipal**	**Industrial**
Acute Criteria	Annual Average design flow[1]	Recommended: Maximum annual average flow (Code does not specify)	Maximum day design flow	Maximum daily total flow which has occurred under normal operations[2]
Chronic Criteria	Annual Average design flow[1]	Maximum annual average flow OR Maximum 7-day average flow[2]	Annual Average design flow[1] (Same flow rate used to calculate concentration limit)	Same flow rate used to calculate concentration limit: Maximum annual average flow OR maximum 7-day average flow[2]
Human Health, Wildlife, and Taste and Odor Criteria	Annual Average design flow[1]	Maximum annual average flow OR Maximum 30-day average flow[2]	Annual Average design flow[1] (Same flow rate used to calculate concentration limit)	Same flow rate used to calculate concentration limit: Maximum annual average flow OR maximum 30-day average flow[2]

TABLE 3: EFFLUENT FLOW RATES TO USE TO CALCULATE CONCENTRATION AND MASS WQBELS.

1. An alternative flow can be used if it is demonstrated that the design flow is not representative.
2. The department may consider a projected increase in effluent flow that will occur when production is increased or modified, or another wastewater source, including stormwater, is added to an existing wastewater treatment facility. Seasonal and unusual discharger flows are determined on a case by case basis.
3. A separate effluent flow rate may be used to calculate a wet weather mass limit when applicable.

Municipal Facilities (subject to ch. NR 210, Wis. Adm. Code)

The annual average design flow rate can also be referred to as the "average daily design flow", "annual design flow" or "average design flow". This is established as a part of a facility plan reviewed and approved by the department under ss. NR 110.08 and NR 110.09, Wis. Adm. Code. An alternative flow may be used if the facility can demonstrate that the design flow approved with the facility plan is not representative. Examples of reasons that the design flow may not be representative include:

- A reduction in flow due to the closing of an industry that previously contributed a large volume of wastewater to the municipal treatment plant.
- Decreased population of users contributing to the municipal treatment plant. Design flows are either based on estimated population growth or the current population if the population is in decline, so population shrinkage may cause actual flows to be much lower than design flows.
- Upgrades to the collection system that dramatically decreased the amount of inflow and infiltration.

In these types of situations where the design flow is unrepresentatively high for average annual flows expected within the next 20 years, a maximum annual average of flow (like the flow rate used for industrial dischargers) may be a reasonable substitute. Consideration should be given to whether the municipality is expected to experience growth, so that the selected effluent flow substitute doesn't underestimate any future increases in flows. The Department of Administration produces population estimates for each town, Census designated place, village, and city, which can inform this decision.

Situations may also arise when a facility is consistently discharging above their average design flow and the design flow rate may not be a sufficiently protective estimate.

In either situation, the limit calculator should contact the municipal plan review staff and determine an appropriate course of action on a case-by-case basis. The facility representatives/consultants may be able to provide documentation that demonstrates appropriate capacity at the altered flow rate. This would result in the department re-rating the facility, which could change the design flow rates. In some instances, the permit may need to include provisions requiring the facility to assess capacity needs and provide upgrades to accommodate the increased flow rates.

Industrial Facilities (not subject to ch. NR 210, Wis. Adm. Code)
Two effluent flow rate options are given for industrial dischargers for each type of WQBEL (See Table 3). Generally, where a choice is given for industrial effluent flow rates, the maximum annual average flow rate is used for simplicity.

It should be noted that code does not specify what flow rate should be used to calculate concentration limits for industries based on acute criteria, although the flow rate for mass limits is specified. **It is generally recommended that the same maximum annual average flow be used to calculate acute criteria concentration limits for industries,** since this matches the flow typically used for other types of limits**.** Since most industrial facilities discharge to a very large receiving water where limits will equal 2×ATC, and most of the remaining industries discharge to zero or very low flow waters where limits will equal criteria, the effluent flow rate used in acute limit calculation typically does not make a significant difference for industrial dischargers. However, if a discharge situation falls somewhere between these two extremes, the limit calculator may need to use best professional judgment to select an effluent flow rate which will be sufficiently protective of water quality.

Other Design Flows
Flows other than those summarized in Table 3 may be needed to calculate mass limits for municipal dischargers. The daily maximum design flow is needed to calculate any mass limits based on acute criteria for discharges subject to ch. NR 210, Wis. Adm. Code. Weekly and monthly design flows may be needed to calculate wet weather mass limits (see Section 3.5). Ideally, design flows from an approved facilities plan should be used for these purposes. An annual average design flow is always provided in facilities plans, but 30-day, 7-day, and daily maximum design flows are not always available.

If these flows are needed and not available, the following method may be used to estimate maximum design flows using a peaking factor. A continuous daily effluent flow record is needed to use this method. When selecting flow data to use, it may be appropriate to use best professional judgement and exclude certain extreme values if they are due to unusual events that are not expected to reoccur.

$$Max\ Design\ Flow = Average\ Design\ Flow \times Peaking\ Factor$$

For a Daily Max Design Flow:

$$Peaking\ Factor_{Day} = \frac{Actual\ Max\ Daily\ Flow}{Actual\ Average\ Flow}$$

For a 7-Day Max Design Flow:

$$Peaking\ Factor_{Week} = \frac{Actual\ Max\ 7 - day\ Average\ Flow}{Actual\ Average\ Flow}$$

For a 30-Day Max Design Flow:

$$Peaking\ Factor_{Month} = \frac{Actual\ Max\ 30 - day\ Average\ Flow}{Actual\ Average\ Flow}$$

Staff should always reference the source of the design flow in the WQBEL memo and note when design flows have been estimated using these equations or another method.

Section 3.3: Background Pollutant Concentrations

Section 106.06(4)(e), Wis. Adm. Code requires that representative background concentrations of toxic or organoleptic substances be used when deriving chemical-specific WQBELs. In order to quantify how much dilution is available in the receiving water, the limit calculator should determine the existing instream pollutant concentration (Cs) prior to discharge.

$$WQBEL = \frac{WQC \times (Q_s + [1 - f]Q_e) - (Q_s - fQ_e) \times \boldsymbol{C_s}}{Q_e}$$

An estimate of instream pollutant concentrations can be obtained using several different methods:

- Ideally, background data should be from the receiving water, just upstream of the discharge site. Other locations in the receiving water are also acceptable as long as they are not directly influenced by the discharge or the discharge from another facility (s. NR 106.06(4)(e), Wis. Adm. Code).
- If data is not available at the discharge site, data from another similar site may be used. Similar sites include those waters that are expected to have comparable hydrology and water chemistry, ideally geographically nearby. The Target Watershed Site Selection Tool in Water Condition Viewer can be used to help identify a similar waterbody.
- For some pollutants, a basin or watershed average may be appropriate. Consideration should be given to how much surface water concentrations of the pollutant vary over distances and types of waterbodies (large rivers, small streams, etc.) and any other factors that may influence background concentrations before using this method.
- Background temperature data for different types of receiving waters are provided in Table 2 of ch. NR 102, Wis. Adm. Code.

- If no relevant background data can be obtained, the department may use zero as the background data for most pollutants*. Staff should avoid this assumption if there is reason to believe that background pollutants may be present at a significant concentration which could affect permitting outcomes.

*An exception to this is mercury. Unlike other toxic parameters, in absence of site-specific information, it is typically assumed that mercury concentrations exceed the wildlife mercury criteria of 1.3 ng/L. Based on surface water data in the SWIMS database from 2002 to 2017, average mercury concentrations are greater than 1.3 ng/L in about 70% of surface waters. However, any representative mercury receiving water data should be used in place of this assumption. For example, available monitoring data has shown that mercury concentrations in Lake Michigan and Lake Superior are consistently below the 1.3 ng/L criteria.

To average background receiving water data, geometric means should be used for all parameters except for pH, which uses an arithmetic mean (s. NR 106.06(5)(a), Wis. Adm. Code). Since geometric means cannot be calculated with any zero values, any non-detect results should be substituted with one half of the LOD in accordance with s. NR 106.06(4)(e)3, Wis. Adm. Code.

Data Sources

The SWIMS database includes surface water concentration data for a variety of substances. When selecting receiving water data, check the project name and the purpose of the monitoring event. Some of the data stored in SWAMP is from storm events, spills, or other atypical events that should not be included in background assumptions. Some of this data that has already been screened is summarized in SWDV, the WPDES Viewer, and other mapping tools for quick use.

Some permittees measure pollutant levels in their intake water prior to use. These levels are considered to be representative of the receiving water and may be used to determine background levels. Therefore, staff should check for any nearby industries located on the same receiving water that may monitor intake pollutant levels.

Seasonal and Low-Flow Specific Data

Several parameters related to limit calculation are known to vary seasonally. Seasonal differences in ambient temperature are accounted for in the monthly ambient temperatures listed in ch. NR 102, Wis. Adm. Code. Other parameters that may vary seasonally include dissolved oxygen, pH, hardness, and ammonia-nitrogen. Administrative code allows for seasonal adjustment of both the background water quality parameters related to toxicity (s. NR 106.06(5)(a)2, Wis. Adm. Code.) and the pollutants themselves (s. NR 106.06(4)(e)2, Wis. Adm. Code).

There is rarely sufficient data available to calculate seasonal averages for these parameters. However, when a large dataset for an instream parameter is available, and it is known that the parameter varies seasonally, this should be accounted for by calculating seasonal averages for the parameter.

Similarly, these same parameters may also vary with stream flow. Since limit calculation procedures model conditions when the receiving water flow is lowest, the receiving water parameters should also reflect this condition. If a sufficiently large dataset is available, and it is known that the parameter is correlated with stream flow, the calculated background value should be based on data from low flow conditions. This method would be most applicable for ammonia-nitrogen limit calculations, and methods for calculating this are described in the guidance document *Calculating Ammonia Nitrogen Effluent Limitations for Surface Water Discharges*.

Section 3.4: Water Quality Parameters

Some toxic substances have water quality criteria related to one or more water quality parameters such as hardness, pH, and/or temperature. When this is the case, the department should calculate WQBELs that take those parameters into consideration.

Hardness

Hardness affects the toxicity of some metals, including cadmium, chromium, copper, lead, nickel, and zinc. At lower hardness these metals are more toxic. Typically, effluent hardness is used for acute criteria and receiving water hardness is used for chronic criteria. This is due to the assumption that effluent conditions are controlling in the area immediately after discharge and receiving water concentrations are controlling over longer distances.

Effluent hardness data is reported on permit applications and sometimes with permit required monitoring if the permit includes applicable metals limits or monitoring. Additionally, hardness data for both effluent and receiving waters is usually reported during WET testing and can be found on WET reports located in SWAMP. (Instructions for creating reports from the WET database are located in the SWAMP user manual on the wastewater intranet, see pp. 24-26.) Some surface water hardness data is recorded in SWIMS. If multiple sources of hardness data are available, all available data should be utilized. Similar to background data, hardness results should be a geometric mean.

If receiving water hardness data is not available, hardness information from a nearby waterbody may be used. If the receiving water has low or no dilution, effluent hardness may also be substituted for receiving water hardness.

In some situations, a “mix hardness” (effluent + receiving water) may be appropriate for use in place of receiving water hardness. Mix hardness evaluations are appropriate in situations where the following are true:

1. Mix hardness is significantly different from the background water hardness
2. The Qe:Qs ratio should be fairly high (little dilution is available)
3. Hardness added through the effluent is not likely to be precipitated or otherwise removed when mixed with the receiving water. This is most likely to occur in areas of low pH and/or low hardness in background waters.

To determine if hardness may precipitate out, the saturation pH must be calculated and compared to the receiving water pH. Equations and methods to estimate saturation pH this are provided in *Process Chemistry for Water and Wastewater Treatment* (Benefield, Judkins, and Weand) and summarized in Appendix B.

pH

Effluent and receiving water pH effects the toxicity of some substances, including ammonia-nitrogen and pentachlorophenol. Similar to hardness, effluent pH should be used when calculating acute criteria, and receiving water pH should be used when calculating chronic criteria. When effluent or receiving water pH is needed, an arithmetic mean, rather than geometric mean of available representative data should be utilized.

Temperature

Ammonia-nitrogen is the only compound for which the department has promulgated water quality criteria that are influenced by temperature (s. NR 105.05 Table 4B, Wis. Adm. Code). Methods for calculating ammonia-nitrogen limits are described in the guidance *Calculating Ammonia Nitrogen Effluent Limitations for Surface Water Discharges*.

Section 3.5: Mass Limitations

While concentration limits ensure that toxics are not present in toxic amounts, mass limits are needed in order to limit the total load of pollutants that are discharged and serve as a basis for the antidegradation and antibacksliding portions of the WPDES program. In accordance with s. NR 106.07(2), Wis. Adm. Code, all limits calculated under ch. NR 106 should be expressed as both a mass and concentration limit except where a mass limit has been determined to be impracticable.

Mass limits are generally not required for the following pollutants:

- pH (40 CFR 122.45(f))
- Dissolved Oxygen
- Bacteria
- Ammonia-nitrogen (except for situations with multiple dischargers or dischargers to ORW or ERW, s. NR 106.32(5)(b), Wis. Adm. Code)
- Chlorine (s. NR 106.07(2), Wis. Adm. Code)
- Temperature (40 CFR 122.45(f))
- Whole Effluent Toxicity (WET)

The mass limit is calculated using the following “pounds” equation:

$$Mass\ Limit\ \left(\frac{lbs}{day}\right) = Concentration\ Limit\ \left(\frac{mg}{L}\right) \times Effluent\ Flow\ Rate\ (MGD) \times 8.34$$

(8.34 is a unit conversion factor)

The appropriate effluent flow rate to use to calculate a mass limit varies based on the type of limit and type of facility. Table 4 summarizes the flows used to calculate each kind of mass limit as specified under s. NR 106.07(2), Wis. Adm. Code.

	Municipal (subject to NR 210)	**Industrial (non-NR 210)**
Acute Criteria	Maximum day design flow	Maximum daily total flow which has occurred under normal operations[2]
Chronic Criteria	Annual average design flow[1] (Same flow rate used to calculate concentration limit)	Same flow rate used to calculate concentration limit: Maximum annual average flow OR maximum 7-day average flow[2]
Human Health, Wildlife, and Taste and Odor Criteria	Annual average design flow[1] (Same flow rate used to calculate concentration limit)	Same flow rate used to calculate concentration limit: Maximum annual average flow OR maximum 30-day average flow[2]

TABLE 4: FLOWS TO USE TO CALCULATE MASS LIMITS (MGD) ACCORDING TO S. NR 106.07(2), WIS. ADM. CODE

1. An alternative flow can be used if it is demonstrated that the design flow is not representative.
2. The department may consider a projected increase in effluent flow that will occur when production is increased or modified, or another wastewater source, including storm water, that is added to an existing wastewater treatment facility.

Wet Weather Mass Limits

For year-round municipal dischargers, whenever a mass limit is included in the permit for a limit based on chronic, wildlife, human health, or taste and odor criteria, a wet weather mass limit should also be included in accordance with s. NR 106.07(9), Wis. Adm. Code. Both limits would be included in the permit and the wet weather limit would apply when "the mass discharge level exceeds the mass limitation calculated…and when the permittee demonstrates to the satisfaction of the department that the discharge exceedance is caused by and occurs during a wet weather event. For purposes of this subsection, a wet weather event occurs during and immediately following periods of precipitation or snowmelt, including but not limited to rain, sleet, snow, hail or melting snow, during which water from the precipitation, snowmelt or elevated groundwater enters the sewerage system through infiltration or inflow, or both." s. NR 106.07(9), Wis. Adm. Code.

Applicability:

Wet weather limits are given in municipal discharger permits for toxics such as chloride, copper, zinc, and other toxics which are expressed as both concentration and mass limits. They only apply to chronic, human health and wildlife limits and are expressed as weekly and monthly average limits.

For limits based on chronic criteria or chronic secondary values:

$$Wet\ Weather\ Mass\ Limit\ (\frac{lbs}{day}) = Concentration\ Limit\ (\frac{mg}{L})\ \times 7\ day\ design\ flow\ \times 8.34$$

For limits based on wildlife, human health criteria or secondary values, or taste and odor criteria:

$$Wet\ Weather\ Mass\ Limit\ (\frac{lbs}{day}) = Concentration\ Limit\ (\frac{mg}{L})\ \times 30\ day\ design\ flow\ \times 8.34$$

See Section 3.2 for procedures to estimate weekly or monthly design flows when these flows are unavailable.

Both the mass limit and wet weather mass limits should be included in the permit. If the facility demonstrates that a mass limit exceedance is due to a wet weather event as described in s. NR 106.07(9), Wis. Adm. Code, the wet weather mass limit would apply for compliance determination purposes during that event.

Wet weather limits do not apply to:

- Acute limits
- Approved water quality standards variances
- Industrial dischargers (since it only applies to facilities subject to ch. NR 210)
- Seasonal Dischargers

Section 3.6: Special Evaluations

Intake Credits

Section NR 106.06(6), Wis. Adm. Code, allows a facility to demonstrate that a pollutant present in intake water, which is passed through the facility and discharged does not cause, have the reasonable potential to cause, or contribute to the excursion of water quality criteria in the receiving water. The demonstration has five conditions, all of which must be met:

1. The permittee withdraws 100 percent of its intake water containing the substance from the same body of water into which the discharge is made;
2. The permittee does not contribute any additional mass of the substance to the wastewater;
3. The permittee does not alter the substance chemically or physically in a manner that would cause adverse water quality impacts to occur that would not occur if the pollutants were left in-stream;
4. The permittee does not increase the concentration at the edge of the mixing zone, or at the point of discharge if a mixing zone is not allowed, as compared to the concentration in the intake water, unless the increased concentration does not cause or contribute to an excursion above an applicable water quality standard; and
5. The timing and location of the discharge would not cause adverse water quality impacts to occur that would not occur if the identified intake pollutant were left instream.

If all five criteria are met, there is no reasonable potential and no limits are required. According to s. NR 106.06(6)(c), Wis. Code, if not all the conditions are met, then:

- In the Great Lakes Basin (direct dischargers to the Great Lakes and tributaries of the Great Lakes), Limit = most stringent criterion.
- Outside Great Lakes Basin AND same waterbody, Limit = background concentration
- Outside Great Lakes Basin AND different waterbody, Limit = most stringent criterion

If portions of the discharge fall under both the second and third points, the limit will be calculated using both approaches in a flow-proportional manner (NR 106.06(6)(c)2.c, Wis. Adm. Code).

These procedures are summarized in Figure 3 below.

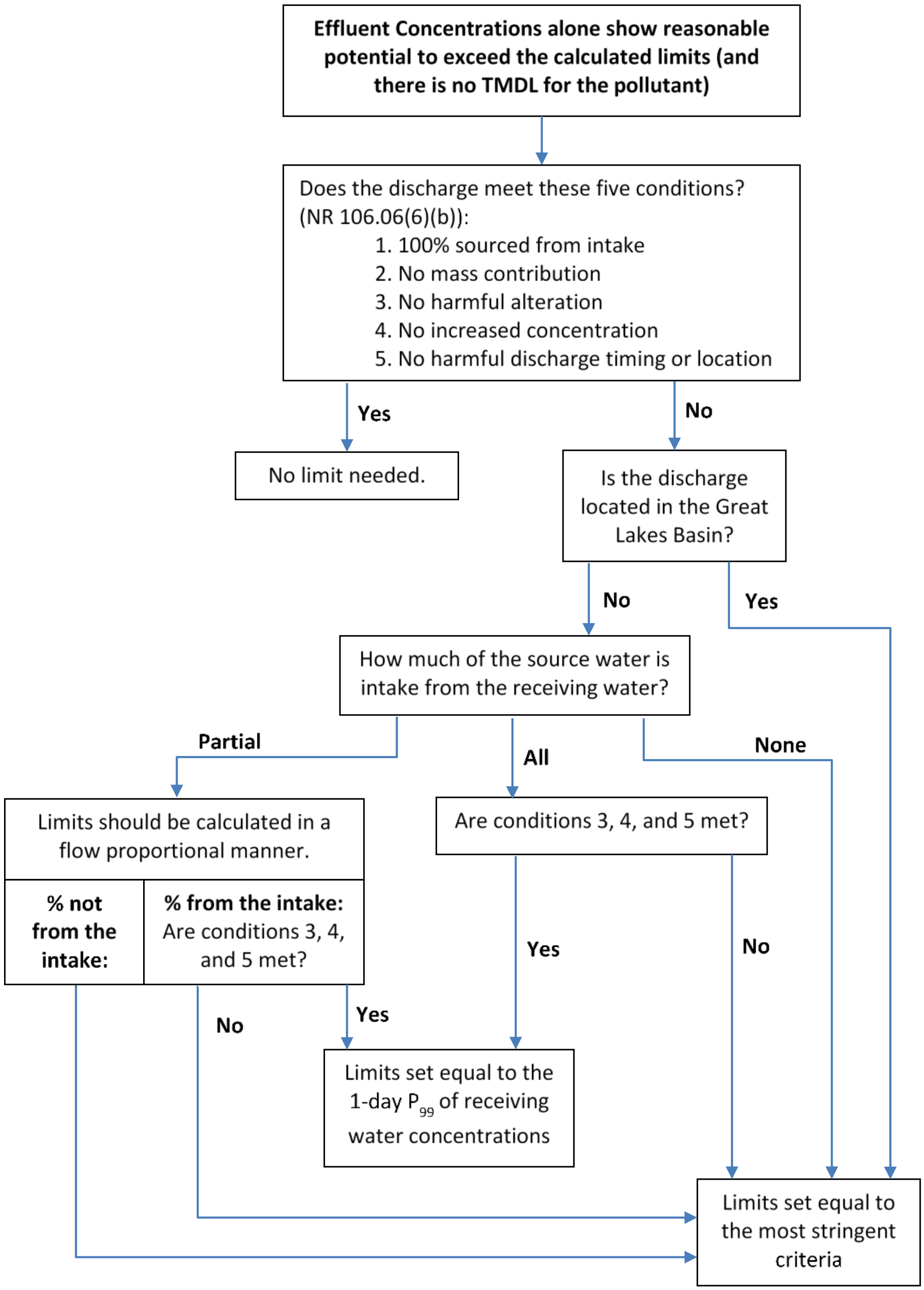


FIGURE 3: INTAKE CREDITS DECISION FLOW CHART

Ideally, the evaluation of items 2 and 4 should be based on paired sampling data from the intake water and the effluent. If a facility has a hydraulic retention time longer than one day, this should be taken into account when planning paired sampling. Each paired sampling event can be examined to determine if the facility increases the pollutant concentration and loading and if the intake concentration seems to determine the effluent concentration. Often, this comparison will make it obvious whether or not the pollutant load is sourced from the receiving water, but if not, a statistical method could be used. A t-test can be used to support the determination of whether or not paired data are significantly different. The P_{99} values of representative intake and effluent data can also be compared to demonstrate there is no increase in mass or concentration.

Keep in mind that if there is a TMDL, the limits for that pollutant would be based on the TMDL. TMDL limits would be included in a permit regardless of pollutant concentrations in the intake water.

Definition of same body of water (Item 1 in the flow chart)
“Same waterbody” is defined in s. NR 106.03(11m), Wis. Adm. Code, as “hydrologically connected waters of the State with similar water quality characteristics in which a pollutant can travel between in a reasonable period of time without significantly changing chemically or physically. Hydrological connections can include surface and groundwater connections.”

Additional information is included in s. NR 106.06(6)(e), Wis. Adm. Code, regarding the same waterbody. An intake pollutant in the source water is considered to be from the same waterbody as the receiving water of the discharge if the permittee successfully demonstrates all of the following to the department:

1. That the pollutant would have reached the outfall point in the receiving water within a reasonable period had it not been withdrawn by the permittee.
2. That the background concentration of the pollutant in the receiving water is at a similar concentration level to that in the intake water.
3. That other water quality characteristics, including temperature, pH and hardness are similar in the intake water and the receiving water.

Mixing Zone Phase-out for BCCs

Mixing zones may not be allowed for new or expanded dischargers of BCCs into the Great Lakes system, such as mercury, in accordance with s. NR 106.06(2)(bg), Wis. Adm. Code. However, under some circumstances existing discharges to the Great Lakes system may continue to be allowed a mixing zone for BCCs according to s. NR 106.06(2)(br), Wis. Adm. Code. An exception to the mixing zone phase-out may be granted for:

- Water conservation – A mixing zone may be granted if the permittee demonstrates that failure to grant a mixing zone for the BCC would preclude water conservation measures that would lead to an overall load reduction of the BCC.
- Technical and economic considerations –
    - For the BCC discharged, the permittee is in compliance with and will continue to comply with the WPDES permit requirements and ch. NR 106.
    - The permittee has reduced and will continue to reduce loading of the BCC to the maximum extent possible such that additional controls or pollution prevention measures would result in unreasonable economic effects on the discharger or affected community because the controls or measures are not feasible or cost effective.

This is particularly relevant for mercury discharges directly to the Great Lakes, because unlike most other waters in the state, Great Lakes concentrations of mercury are below criteria.

An exception to the mixing zone phase out requires that (s. NR 106.06(2)(br), Wis. Adm. Code):

- The approved mixing zone is no larger than necessary.
- Water quality criteria or secondary value for the BCC is met at the edge of the mixing zone.
- The permit shall contain a limit for the BCC that shall not be less stringent than a limit that was effective on November 6, 2000.
- The permit shall include ambient water quality monitoring if the department determines these requirements are appropriate to ensure compliance with water quality criteria and consistency with any applicable TMDL.
- The permit shall include a pollutant minimization plan.
- Approval of a mixing zone shall cover one permit term and re-evaluation is required at each permit reissuance.
- The decision to grant a mixing zone be documented in the permit fact sheet.

This process has similar requirements to the variance process, however the department has the authority to approve mixing zone exemptions and they do not need to be sent to EPA for approval.

If the conditions listed above will be met, the following process should be used to calculate a limit for an exception to the mixing zone phase-out:

1. Calculate the limit without a mixing zone (WQBEL = WQC).
2. If the effluent 30-day P_{99} > the calculated limit with no mixing zone, reasonable potential is shown and a limit is required.
3. To consider an exception to phase out of mixing zone, calculate the limit using a 10:1 mixing zone.
    a. If the 30-day P_{99} > the calculated limit with a 10:1 mixing zone, an exception to the mixing zone phase-out would not result in an attainable limit. In these situations, the facility may apply for a variance to the water quality standard.
    b. If the 30-day P_{99} < the calculated limit with a 10:1 mixing zone, then a limit equal to the 1-day P_{99} expressed as a daily maximum should be included in the permit with quarterly monitoring
4. Calculate what mixing zone is needed based on the 30-day P_{99} of the effluent data and criterion. This will be less than 10:1 and will be used to describe what mixing zone is being approved for the exception to the phase out of mixing zones for a BCC in Great Lakes basin.

Multiple Discharge Situations

In situations where two outfalls are located close together, WQBELs should be calculated in a way to ensure that the receiving water is not over allocated. Section NR 106.11, Wis. Adm. Code, addresses situations where multiple discharges may be utilizing the same assimilative capacity for a pollutant. The same equation given at the beginning of this chapter would be used to calculate limits for multiple discharges utilizing the same assimilative capacity:

$$WQBEL = \frac{WQC \times (Q_s + [1 - f]Q_e) - (Q_s - fQ_e) \times C_s}{Q_e}$$

Where multiple discharges are in close proximity that the mixing zones overlap, the value of Q_e in the above equation should be modified in order to account for the multiple discharges. The sum of the appropriate effluent flows as specified in s. NR 106.06(4)(d), Wis. Adm. Code, should be substituted for Q_e. When determining the need for effluent limits, the P_{99} values of effluent data (or averages if applicable) for each discharge should be combined in a flow-weighted average and compared to the calculated limit.

If this process triggers the need for effluent limits, a more detailed assessment may be needed. If the modeled combined discharge shows reasonable potential, effluent limits will be needed for all permittees that are discharging the pollutant of concern in the multiple discharge reach.

Chapter 4 – Effluent Data

This chapter includes information on gathering and selecting effluent monitoring data for use in the limit calculation and reasonable potential procedures. Once gathered, some of the effluent characterization data may need to be excluded if it is not representative of current discharge conditions. Effluent data may also need to be interpreted differently in light of the test method and level of detection. Additionally, this chapter covers situations when additional effluent monitoring may be warranted.

Section 4.1: Data Sources

Effluent characterization data may come from several different sources:

- Permit application monitoring: Usually the most extensive variety of effluent monitoring is reported with the permit application (requirements in ch. NR 200, Wis. Adm. Code). For most minor municipal dischargers, this is the only source of metals monitoring data.
- Discharge Monitoring Reports (DMR): Permit required monitoring is electronically reported on DMRs and stored in SWAMP. Typically, the parameters reported on DMRs are pollutants that have already been determined to be a possible concern.
- Whole effluent toxicity testing: WET test endpoints are reported on discharge monitoring reports, with more detailed information (including pH, hardness, and alkalinity data) entered into the WET database in SWAMP. Along with the toxicity results, WET tests may also include data for effluent and receiving water hardness, alkalinity, and pH.
- Additional monitoring data: In some situations, a facility may provide additional monitoring data not required in the permit. Standard permit language requires permittees to report any additional monitoring results if they test more frequently than required by the permit. Whenever possible, additional effluent data should be reported through the DMR system to ensure the information is not lost in the future. If this is not possible for the permittee, the data should ideally be entered into SWAMP monitoring data by department staff.

All effluent data sources and the date ranges selected should be specified in the WQBEL memo.

Section 4.2: Representative Data

In some situations, effluent data may be determined to be not representative and excluded from reasonable potential determinations. In accordance with s. NR 106.05(3), Wis. Adm. Code, only representative data should be used for reasonable potential determinations. Effluent data should not be excluded solely because it is significantly different than the rest of the dataset. If effluent is naturally variable, this should be captured when considering reasonable potential. The following list includes some possible reasons that excluding effluent data may be justified:

- Lab qualified data: The lab may include notations about quality control exceedances or other errors.

- Evidence of improper sample collection, preservation or holding times.
- Significant facility changes: This could include major changes in the treatment system, new industrial contributors or shut down of industrial contributors. For industrial discharges, this could be a change in processes or production rates. Many facilities change operations and make upgrades frequently, and not all monitoring data needs to be considered unrepresentative because of these changes. Consideration should be given to how the operation change or upgrade may impact effluent quality. In some situations, it is appropriate to exclude data for a few parameters and accept data for other parameters.

When effluent data is excluded from the evaluation, a justification should be documented in the WQBEL memo.

Data should generally not be excluded without replacement data in these situations:

- Highly variable event or “upset events” that occur frequently: While data may be considered not representative if it occurs during some abnormal, upset condition, care should be taken that data is not excluded when these kinds of upsets are a regular occurrence. If upset events are occurring regularly, effluent data from those events may actually be representative of the facility’s normal effluent variability. For example, if a high value is obtained during a regular filter backwash, this value should not be excluded since backwashing is a normal part of the facility operations and is expected to reoccur. However, if the facility responds by making changes to their operations that would avoid those high values in the future, the data may be excluded.
- Misreported data: If it is suspected that data has been reported incorrectly, the department should contact the permittee and request more information. Lab documents from the testing can be used to correct or confirm the data. As long as some documentation is available, misreported data should be corrected rather than thrown out.
- Data with unacceptable LOD: Effluent data with an unacceptable LOD should be replaced rather than ignored. If the limit is below the reported limit of detection, s. NR 106.07(6)(a), Wis. Adm. Code, requires that the permittee perform monitoring with whatever test method produces the lowest limit of detection. If this situation arises, the facility should redo the test with an acceptable test method, rather than throwing out data for the parameter completely.

Section 4.3: Small Datasets

In accordance with ss. NR 105.05(5) and (6), Wis. Adm. Code, when at least 11 detect sample results are available, a P_{99} may be calculated and compared to the limit, but if less than 11 detects are available, an arithmetic mean should be calculated and compared to one fifth of the limit. Because effluent data is conservatively compared to one fifth of the limit, limits are often triggered based on small data sets.

When a new effluent limit is triggered based on one of very few effluent results, it is usually best to obtain more effluent data prior to permit reissuance. Subsequent effluent monitoring very often demonstrates that a limit is not actually needed. If limits are included in a permit based on small data sets, this may lead to the need for a permit modification in order to remove the limit and/or compliance schedules or variance requests that are unnecessary. These situations should be avoided whenever possible by obtaining a larger set of representative effluent data.

When a new limit is triggered based on a small data set, an effort should be made to add more data to the analysis by either using representative effluent data from a previous permit term or obtaining new effluent monitoring data. If there have not been any significant changes to the treatment system, facility operations or effluent quality, representative effluent monitoring data from a previous permit term may be used in the reasonable potential analysis. If such effluent data is available, this may eliminate or reduce the need to collect additional effluent monitoring data.

If new monitoring data is needed, the limit calculator should notify the compliance staff, permit drafter, and permittee and request additional monitoring data. The request should be made as soon as possible to allow the facility time to perform more sampling and avoid delaying permit reissuance.

It is important to note that there is no requirement in code or statute for the facility to perform additional monitoring. Any additional monitoring not required by the permit or ch. NR 200, Wis. Adm. Code is voluntary, but it is usually in the best interest of the facility to perform. The permittee will have several options of how to proceed, and the best option will depend on the situation:

1. No action and accept effluent limits in the reissued permit. A compliance schedule may be included in the permit depending on the situation. In some cases, the facility may apply for a variance. If additional monitoring data collected over the permit term shows no need for a limit, the permit may be modified or reissued to remove the limit as long as anti-backsliding requirements are met (see Chapter 10).
2. If applicable, offer sufficient explanation why some or all of the provided data is not representative of current discharge conditions. If all effluent data is not representative, additional monitoring should be required. If only some of the data is not representative, additional monitoring data still might be needed in order to demonstrate that a limit is not required.
3. Provide additional monitoring data:
    a. If at least 11 detect results that are representative of the discharge are available and the P_{99} of detected values is less than the limit, then no limit is required.
    b. If less than 11 detects are available and the average is less than one fifth of the limit, then no limit is required (non-detect values are substituted with zero when calculating the average).

If a facility opts to provide additional monitoring data, monitoring plans may need to change based on the test results. In some cases, less than 11 monitoring results may be needed to show that the average value is less than one fifth of the limit. On the other hand, if some of the results come back as non-detect, more than 11 tests may be needed in order to calculate a P_{99}. An effort should be made to advise the permittee on the most practical course of action without recommending excessive monitoring. One possible monitoring plan is to first gather 2-3 additional samples and evaluate this data before requesting a full 11 samples.

Any additional monitoring should be timed with sufficient gaps of time in between tests. For example, testing on concurrent days should be avoided, if this results in redundant data or data that does not accurately capture effluent variability. As a rule of thumb, the time between tests should be at least as long as the hydraulic retention time of the treatment plant to rule out serial correlation.

Section 4.4: LOD and LOQ

The limit of detection (LOD) as defined in s. NR 149.03(41), Wis. Adm. Code, is “the lowest concentration or amount of analyte that can be identified, measured, and reported with confidence that the concentration is not a false positive value.” The definition goes on to state that for department purposes, the LOD is approximately equal to the method detection limit (MDL), which is commonly referenced by EPA.

Chapter NR 105, Wis. Adm. Code, regulates a number of pollutants at concentration levels which may not be detectable using currently available testing methods. For these pollutants, it may not be possible to determine if effluent data that is reported below the LOD exceeds calculated effluent limits. For this reason, it is important to ensure that effluent data provided for these pollutants uses testing method with the lowest possible LOD.

DNR certified labs are required to re-calculate an LOD for each test method at least annually in accordance with s. NR 149.48(2), Wis. Adm. Code. Section NR 106.07(6), Wis. Adm. Code, requires use of the test method with the lowest LOD when the limit is below the LOD. A typically achievable LOD (or MDL if LOD is not given) range may be found in the approved method documents for the pollutant. This range can be compared to the reported LOD to determine if it is reasonable.

- If the non-detect result’s LOD is less than or within an order of magnitude of the expected LOD, it may be accepted.
- If the non-detect result’s LOD is more than an order of magnitude greater than the expected LOD, the facility and/or lab should provide an explanation for the high LOD. Staff should be satisfied that an alternative test, technique or lab could not produce lower results. If the explanation is not satisfactory, the facility should retest or select a different lab to obtain a lower LOD.

In accordance with s. NR 106.05(7)(a), Wis. Adm. Code, effluent monitoring results below the LOD are considered to be zero for limit calculation purposes as long as an acceptable test method is used. But if a monitoring result is between the LOD and limit of quantification (LOQ), it may be used as reported for limit calculation purposes.

According to s. NR 149.03(42), Wis. Adm. Code, limit of quantitation means the lowest concentration or amount of an analyte for which quantitative results can be obtained. If a limit is to be required based on effluent monitoring data which is less than the LOQ, the fact that the exact concentration of the substance is unknown should factor into the decision process. Additional monitoring data prior to permit reissuance may be warranted in these cases. The general process for handling effluent data based on its LOD and LOQ values in relation to the limit is summarized in Table 5.

Limit	Effluent result	Action
Limit < LOD or LOQ	Effluent result > LOQ	The LOD and LOQ must be the lowest reasonably achievable. Reasonable potential to exceed the limit.
Limit < LOD or LOQ	Effluent result < LOD	The LOD and LOQ must be the lowest reasonably achievable. No limit needed.
Limit > LOD	Effluent result < LOD	No limit needed.
Any Limit	Effluent result > LOD but < LOQ	Effluent result may be used as reported to determine reasonable potential. Effluent result quantity is uncertain, so additional monitoring may be warranted.

TABLE 5: LOD AND LOQ LIMIT DETERMINATIONS FOR SITUATIONS WITH A SINGLE EFFLUENT TEST RESULT

If limits for these substances are included in the permit, compliance with the limits below the LOD or LOQ must be determined in accordance with s. NR 106.07(6), Wis. Adm. Code.

If the test method used is not acceptable, the effluent data less than the limit of detection should be excluded in accordance with s. NR 106.05(7)(b), Wis. Adm. Code. If there is a large difference in the reported LODs (a factor of 10 or more), the difference is possibly due to a change in test method, and this should be investigated. If the test method is determined to be the cause, the non-detect results with the higher LOD should not be considered representative. Any detect results using the same method may also not be representative.

Chapter 5 – Determining the Need for Limits

According to s. NR 205.067(1)(a), Wis. Adm. Code, WQBELs are required to be included in permits when it is determined that there is reasonable potential to exceed them. This chapter discusses possible ways that reasonable potential may be demonstrated or that WQBELs may otherwise be required.

Section 5.1: Reasonable Potential

1. If, based on available effluent data that is representative of current conditions, a calculated limitation would be exceeded, that limit must be included in a permit (s. NR 106.05(3), Wis. Adm. Code). Specifically, reasonable potential to exceed a limit is shown if:
    - Single result > Daily Maximum WQBEL
    - 4 Consecutive Day Average > Weekly Average WQBEL
    - 30 Consecutive Day Average > Monthly Average WQBEL

2. If 11 or more detected effluent results are available, a P_{99} value may be calculated and compared directly to the effluent limit. Reasonable potential to exceed a limit is shown if:
    - 1-day P_{99} > Daily Maximum WQBEL
    - 4-day P_{99} > Weekly Average WQBEL
    - 30-day P_{99} > Monthly Average WQBEL

3. If fewer than 11 detected effluent results are available, an arithmetic mean value should be calculated instead of a P_{99}. Non-detectable results should be included as zeroes when calculating the mean, as long as the level of detection and the test methods used to generate those results are acceptable (s. NR 106.05(7)). If the mean effluent concentration exceeds 1/5 of a calculated limitation, that limit must be included in the permit (s. NR 106.05(6), Wis. Adm. Code). The 1/5 factor serves as a surrogate for effluent variability and is an estimate of the expected relationship between the mean and P_{99}. This same method applies for all limit averaging periods. Reasonable potential to exceed a limit is shown if:
    - Average > 1/5 of any WQBEL

All the above evaluations are based on representative effluent data. But if no such data is available, WQBELs may still be included in a permit:

> *"If representative discharge data are not available for a substance, the department may include water quality–based effluent limitations in a permit if, in the judgment of the department, water quality standards will be exceeded if the discharge of the substance is not limited." (s. NR 106.05(8), Wis. Adm. Code)*

P_{99} Calculation

The P_{99} value represents a concentration that is estimated to be exceeded only 1% of the time and is calculated using the formulas in s. NR 106.05(5), Wis. Adm. Code. While it is sometimes referred to as an upper 99th percentile, it should be noted that a P_{99} value is close to, but not exactly the same as an upper 99th percentile as it is most commonly determined.

Three types of P_{99}s are used in limit calculation evaluations: 1-day, 4-day, and 30-day. A 1-day P_{99} is an estimate of the highest expected single result and a 4-day P_{99} is an estimate of the highest expected 4-day average, and so on.

A minimum of at least 11 detected results must be used to calculate a P_{99} value. This is because 11 is the assumed threshold between variability of an effluent based on actual data and variability associated with small database size (degrees of freedom). Having a sample size of at least 11 makes it more likely that the variability in the dataset reflects actual effluent variability and not an effect of a small dataset.

The calculation of a P_{99} is dependent on both the arithmetic mean and the standard deviation of the dataset. If the mean and standard deviation are higher, the resulting P_{99} value will also be higher. This means that sometimes the addition of a sample result much lower than the rest of the dataset may actually increase the P_{99} value. Since a low value increases the variability of the dataset, there is greater uncertainty about the maximum expected values and the P_{99} calculation accounts for this by estimating a higher value.

Section 5.2: Other Reasons to Include WQBELs in Permits

Outside of a reasonable potential determination, there are a few reasons that WQBELs may be required in a permit regardless of pollutant levels in the effluent:

1. **Categorical Limits:** In accordance with s. NR 106.04(1), Wis. Adm. Code, whenever a categorical limit that is less restrictive than a WQBEL is established in a permit, the WQBEL must also be included in the permit. Note that this is not based on an evaluation of effluent data. For example, BOD WQBELs are included in permits for municipal dischargers when they are more restrictive than the categorical limits in ch. NR 210, Wis. Adm. Code.
2. **Located within a TMDL:** When the discharge is located in a TMDL area and a wasteload allocation is given for the pollutant of concern, WLA-derived WQBELs are required according to s. NR 212.76, Wis. Adm. Code regardless of effluent pollutant levels. Additional WQBELs to protect water quality of the direct receiving water calculated using the procedures in this guidance may also be required depending on how the TMDL is written. See the "TMDL Implementation Guidance for Wastewater" and the specific TMDL report for more information.
3. **Pollutants with assumed reasonable potential (chlorine and pH)**: In accordance with s. NR 205.067(1)(b), Wis. Adm. Code, WQBELs may be included in the permit whenever the department determines that a discharge may cause or contribute to an excursion of water quality standards. For

this reason, WQBELs are included in permits for some substances by default, assuming that they will have reasonable potential. For example, when a facility treats effluent with chlorine, WQBELs for total residual chlorine are included in the permit to ensure proper removal prior to discharge. Limits are also included for pH to ensure that water quality criteria in s. NR 102.04(4)(c), Wis. Adm. Code, are met.

Section 5.3: Determining the Need for Permit Monitoring

In accordance with s. NR 106.05(9), Wis. Adm. Code, monitoring requirements may be included in a permit for any toxic or organoleptic substances when it is determined to be necessary. Monitoring should be recommended if an effluent is close to showing reasonable potential. For example, if four copper monitoring results are available, and the average is less than but close to one fifth of the calculated limit, the limit memo should recommend at least 11 copper samples be collected in the next permit term. This will ensure that sufficient data is available at the next permit reissuance to more accurately determine if there is reasonable potential to exceed the limits.

Other possible reasons to require permit monitoring may include:

- The test method LOD is close to or higher than the limit and a more sensitive test method is available.
- There is reason to believe that the available effluent data may not be representative.
- A substance is suspected to be present in the effluent at a level of concern due to the type of discharger, known industrial contributors, or other operations information.

Chapter 6 – Pollutant Types: Toxics

The previous chapters covered the general process for determining applicable water quality criteria, calculating WQBELs, and determining if WQBELs should be included in the permit. Chapters 6 and 7 cover how these processes differ for different categories of pollutants and exceptions or special considerations for specific pollutants.

Toxics (or “toxic and organoleptic substances” as they are referred to in rule) are those compounds known to exert a toxic effect on aquatic life, wildlife, or humans with water quality criteria listed in ch. NR 105, Wis. Adm. Code.

Section 6.1: Chlorine and Halogens

Chlorine, bromine, iodine or a combination of halogens are often used for disinfection purposes or to prevent bio-fouling of cooling lines or other equipment. When a permittee adds chlorine or other halogens for treatment, the department automatically concludes that there is reasonable potential to exceed the limit as allowed under ss. NR 106.05(8) and NR 205.067(1)(b), Wis. Adm. Code. Exceptions to this may be allowed for any halogens used in treatment which are not expected to be discharged (for example, when used in treatment of source water prior to a biological treatment process).

Daily maximum chlorine limits are included in the permit whenever chlorine may be discharged. If the receiving water does not have a high level of dilution, weekly average limits may also be required to ensure that chronic criteria are met in the receiving water.

Total Halogen Limits
There are no official test methods for total residual halogens; however, bromine, iodine and other strong oxidants interfere positively in the test for chlorine. Because of this, methods available for measuring chlorine capture the collective concentration of chlorine, bromine and iodine. Permits for facilities that add chlorine, bromine, or iodine may contain limits and monitoring requirements for “total residual halogens” but the monitoring will use the same test methods as total residual chlorine. In these cases, the WQBEL memo may contain a brief discussion that acknowledges that concentrations of bromine or iodine present in the effluent will be included in the analytical measurement for total residual chlorine.

Pass-through Chlorine
In some cases, including non-contact cooling water discharges, the permittee may not actually add chlorine within the facility, but discharge levels of chlorine still exceed WQBELs due to the chlorine residual present in the public water supply. Public water supplies may also use chloramine to disinfect, which is more persistent than free chlorine. Previously, a portion of ch. NR 106, Wis. Adm. Code, allowed discharge of any additives at a level that would be acceptable in a public water supply, but this provision was removed from code. In these cases, chlorine limits are still required since the discharge

includes pollutants that may cause an exceedance of water quality criteria in the receiving water. This may require a facility to install a dechlorination system.

Dissipation
Unlike most other toxics, chlorine and other halogens do not behave conservatively. In some situations, chlorine may dissipate prior to discharge. Consideration should be given to the processes and retention time that wastewater goes through following chlorination and prior to discharge to determine if chlorine will dissipate prior to discharge. If staff believe that chlorine dissipates completely but they are not certain, a period of monitoring may be warranted to confirm this assumption. Any determinations that chlorine does or does not dissipate prior to discharge should be documented in the WQBEL memo. The sample point may be moved closer to the actual discharge location in order to determine effluent chlorine levels that represent concentrations entering the receiving water.

Section 6.2: Mercury

Background Pollutant Concentrations
For many toxic parameters, background concentrations are assumed to be zero when receiving water concentration data is unavailable. The biggest exception to this is mercury. Unlike other toxic parameters, in the absence of site-specific information, it is assumed that the background mercury concentration exceeds the wildlife mercury criteria of 1.3 ng/L. Surface water data stored in the SWIMS database from 2002 to 2017 shows that this is true in about 70% of surface waters. However, any representative mercury site-specific receiving water data should be used over this assumption. For example, available monitoring data has shown that mercury concentrations in Lake Michigan and Lake Superior are consistently below the 1.3 ng/L criteria.

Because of this, the use of mixing zones for BCCs in the Great Lakes is particularly relevant for mercury. See the discussion on Mixing Zone Phase-outs for BCCs in Section 3.6 for more information.

Effluent Data
In accordance with s. NR 106.145(9)(c), Wis. Adm. Code, any mercury monitoring performed by a facility should be accompanied by a field blank measurement. This measurement serves as an indicator of any contamination that occurred during the sampling event. Section NR 106.145(9)(c)2, Wis. Adm. Code, includes requirements for the values of these field blanks in order for the mercury monitoring data to be used for compliance purposes. These same criteria may be used to screen monitoring data for use in reasonable potential analysis or calculating interim limits.

Mercury results may be excluded from the effluent data set if the field blank measurement is equal to or greater than all the following values:

- 0.5 ng/L, and
- LOD, and
- 1/5 of the sample result from the same day (s. NR 106.145(9)(c)2)

> ...unless the conditions in s. NR 106.145(9)(c)3, Wis. Adm. Code, are met, which require at least three field blank measurement for the day.

In accordance with s. NR 106.145(3), Wis. Adm. Code, if representative mercury effluent data is not available at the time of permit reissuance, the permit may require mercury monitoring at a specified frequency depending on the type of discharger and other discharge conditions.

Minor Municipal Discharges
In accordance with s. NR 106.145(3)(a)3., Wis. Adm. Code, a minor municipal discharger shall monitor and report results of influent and effluent mercury monitoring once every three months if, "there are two or more exceedances in the last five years of the high-quality sludge mercury concentration of 17 mg/kg specified in s. NR 204.07(5)." Each permit term, sludge mercury data from the last five years should be reviewed to determine if effluent mercury monitoring is required.

Section 6.3: Chromium

Chromium naturally occurs in two forms, trivalent (+3) and hexavalent (+6). Hexavalent chromium is the more oxidized form and is more toxic due to its tendency to stay in solution and ability to cross biological membranes. Therefore, the criteria for hexavalent chromium in ch. NR 105, Wis. Adm. Code, are much lower than criteria for trivalent chromium.

The trivalent form, which is the reduced form, tends to become unavailable by adsorbing to solids or complexing with organic material and thus is the less toxic form of chromium. As long as significant organic matter is present, the favored state in most natural waters or wastewaters is the trivalent form. In well-oxygenated waters, or waters low in organic matter (seawater, very clean fresh water or drinking water) chromium will slowly convert to the hexavalent form. But, in general, trivalent chromium levels are expected to make up the majority of the total chromium in waters of the state.

Typically, sample results are provided for both forms of chromium with the permit application. To determine the need for limits, total chromium results may be compared to both the calculated trivalent and hexavalent chromium limits. If limits are triggered using the total chromium data, limits can instead be compared to each specific form of chromium to determine if there is truly reasonable potential to exceed WQBELs.

It should be noted that there is no approved test method for trivalent chromium; trivalent chromium should be reported as total chromium minus the hexavalent chromium result. Be aware that hexavalent chromium testing using chromatography methods is prone to interferences, and often hexavalent chromium results will come back higher than total chromium results. In these cases, only the total chromium data may be used, or the effluent may be retested for hexavalent chromium using a different method.

Section 6.4: Additives and Secondary Values

A secondary value is a temporary concentration of a substance which ensures adequate protection of a designated use until sufficient data is available to calculate a water quality criterion (full definition in s. NR 105.03, Wis. Adm. Code). Secondary values are based on available data and account for the uncertainty of that data by using a safety factor. Secondary values are considered in two main scenarios:

- Substances are detected in the effluent and do not have promulgated criteria
- An additive with an unknown or complex chemical composition is used at the facility and may not be removed by treatment or is otherwise present in the discharge.

The guidance document *Water Quality Review Procedures For Additives, Edition #2* outlines procedures for calculating secondary values. This section covers how these secondary values are used to calculate WQBELs and may be implemented in permits.

Calculating WQBELs based on Secondary Values

The document *Water Quality Review Procedures For Additives, Edition #2* provides guidance on how to calculate secondary values for additives and the basis for WQBELs based on secondary values comes from NR 106.05(1)(b), Wis. Adm. Code. The same procedures are used to calculate secondary values for other substances detected in the effluent that are not additives. Once these secondary values are obtained, limits are calculated using the same procedures used for other water quality criteria as described in Chapter 3. The exception to this is that **no dilution is allowed for secondary acute values (Qs = 0)**. Acute limits are set equal to the secondary acute value, in accordance with s. NR 106.06(3)(b)2, Wis. Adm. Code.

$$WQBEL = SAV$$

WQBELs based on secondary chronic values and all other secondary values are calculated using the same equations for other water quality criteria as listed in s. NR 106.06(4)(b), Wis. Adm. Code, and Chapter 3 of this document. Unless the additive being evaluated is a substance commonly present in natural waters such as sodium chloride, background concentrations of the additive are assumed to be zero. For a common scenario with discharge to a unidirectional water, with no intake (f=0) and Cs=0, the equation for chronic additive limits can be simplified to:

$$WQBEL = SCV \times \frac{Qs + Qe}{Qe}$$

Where:

SCV= Secondary chronic value

Qs = streamflow, 25% of the $7\text{-}Q_{10}$

Qe= effluent flow rate, described in Section 3.2

Detected Substances without Promulgated Criteria

Occasionally, a substance may be detected through permit application monitoring that does not have corresponding water quality criteria. This occurs because there was not sufficient toxicity data available to calculate water quality criteria for the substance at the time ch. NR 105, Wis. Adm. Code was promulgated. If a minimum level of toxicity data is available, the substance may instead be regulated by a secondary value.

Toxicity data may be found in the EPA Ecotox Knowledgebase. If a secondary value needs to be developed, contact an environmental toxicologist in the Water Evaluation Section (currently Meghan Williams). The toxicologist will be able to assist in selecting acceptable toxicity data and ensuring statewide consistency.

Once secondary values are obtained, WQBELs are calculated using the same mass-balance equation as used for other parameters and reasonable potential is determined using the procedures described in Chapter 5. The exception to this is that **no dilution is allowed for secondary acute values**. Acute limits are set equal to the secondary acute value, in accordance with s. NR 106.06(3)(b)2, Wis. Adm. Code.

Additives

Any additives that a facility uses in their process or to aid in the treatment of the effluent may be regulated through secondary values (s. NR 106.05(1)(b), Wis. Adm. Code). This evaluation should be done for all additives that may be discharged to the receiving water if they are not removed by treatment or otherwise consumed.

The procedure for calculating limits and determining reasonable potential for additives is the same as for other pollutants; the differences in handling them result from the unique nature of additives:

- Most additives are regulated by secondary values instead of promulgated water quality criteria.
- For most additives, the effluent concentration cannot be quantified simply with an analytical test.
- The facility controls the amount of additive used. Additive usage is typically fairly constant and the facility is limited to a maximum dosage rate, so the statistical methods used to handle uncertainty for other WQBELs are not relevant for additives.
- Addressing toxicity from an additive can be much simpler than addressing other pollutants. The most common courses of action are to reduce use of the additive or switch to a different product.

In some cases, an additive product may be made up of a chemical for which a water quality criterion already exists. If this is the case, the additive discharge may be regulated by setting limits according to those chemical-specific water quality criteria, and no secondary value needs to be calculated. The applied water quality criteria must capture any possible toxic effects from the additive. For example, chlorine would be regulated through acute and/or chronic chlorine water quality criteria. Sulfuric acid would be regulated through a pH limit, since this substance would not be expected to cause toxicity as long as its effect on pH is limited.

In other cases, an additive may be removed or consumed completely prior to discharge and a secondary value is unnecessary. An example is when chlorine and other additives are used to treat water from a surface water intake structure prior to use in a paper mill. The pretreated intake water will go through the facility's pulp and paper processes and then a secondary treatment process prior to discharge, so the original pretreatment additives are not expected to pass through to the final discharge.

Effluent Additive Levels

The same reasonable potential procedures in s. NR 106.05, Wis. Adm. Code, should be applied to additives. But unlike other pollutants, no effluent monitoring data is typically available for additives. Instead, reasonable potential should be determined based on an estimated effluent concentration. The facility may provide estimated effluent concentrations for each additive, but daily use information (lbs/day or gal/day of the additive) should always be provided. To be conservative, the discharged additive concentration may be calculated using a mass balance with the maximum additive dosage rate and the average effluent flow rate. This is the recommended concentration estimation method when the facility has one main waste stream and the additive is present at relatively constant concentrations. Depending on the facility operations, a more detailed estimation may be needed when, for example, there are multiple waste streams with different additive usage rates which discharge intermittently.

In some cases, additive dissipation or removal may be considered in the estimated effluent concentration. For example, if flocculants (such as ferric or alum) are added to the early stages of a treatment process and are designed to be removed with the solids, it may be reasonable to assume that only a small percentage of the additive, if any, is present in the discharge. In cases like these when the additives are not expected to be discharged, a secondary value may not be required at all. However, if there is uncertainty about the fate of an additive, it should be assumed that some percentage of it could be discharged to surface water. If an additive is treated as non-conservative there should generally be some explanation available on the mode of additive removal, and this should be documented in the WQBEL memo.

Reasonable Potential

As discussed in the *Water Quality Review Procedures For Additives, Edition #2* guidance, the use of an additive should not be approved at a level that would exceed the calculated WQBEL. Before considering reasonable potential, make sure to verify the estimated discharge concentration of additive:

- Consider any removal/degradation of the additive prior to discharge. This requires an explanation or demonstration on the mechanism for removal and a department toxicologist should be included in the discussion.
- Consider dilution from any other in-plant waste streams prior to discharge.
- Check where the product is added in the facility's processes and where the waste stream ultimately ends up. Reported additives are sometimes not actually discharged to surface water.

When the proposed usage rate of an additive would cause the secondary value to be exceeded in the receiving water, several courses of action are possible:

- Include additive usage restriction in the permit
- Permittee decreases product usage
- Permittee switches products
- Permittee provides additional toxicity data to recalculate secondary value

An additive WQBEL (or "use restriction") may be included as a limit in the permit to ensure that additive use does not cause an excursion of the secondary value in the receiving water. An effluent limit is appropriate in cases when facility will not be making changes to eliminate reasonable potential or operations are variable and it's difficult to determine the maximum expected discharge concentration. Limits for additives should typically be expressed as the highest allowed discharge concentration. Since additives are often a mixture of chemical components, this is usually not directly measurable. The facility should instead determine what additive dosage rate ensures compliance with the discharge limit through some calculation (e.g., mass balance, etc.)

Whether or not an additive WQBEL is included in the permit, if the proposed additive usage rate causes an unacceptable level of toxicity, the facility will need to make changes to their additive use plans. If the facility makes changes to their additive usage rates or switches to a less toxic additive, there may no longer be reasonable potential, and a WQBEL may not be necessary. In most situations when an additive usage rate shows reasonable potential to exceed the WQBEL, the facility will make changes to remedy the situation. A WQBEL for the additive is not needed if reasonable potential is not triggered.

Another option for the permittee is obtaining additional toxicity testing data for the additive that can be used to recalculate the secondary value. When more genera of toxicity data are available, a lower safety factor is applied in calculating the secondary value, which may result in a less restrictive secondary value. However, this is not always the case given a new species could be more sensitive to the additive.

The WQBEL memo should clearly state the additive dosage amount or discharge concentration approved for use. The permit will include language that requires written approval from the department before increasing additive usage or using a new additive.

Section 6.5: Dissolved Metals

The expression of toxicity of heavy metals in surface waters for the protection of aquatic life is dependent upon knowledge of the bioavailability of the discharged metal. Standard implementation, through total recoverable limits, of water quality criteria for metals assumes that 100 percent of the discharged metal is bioavailable and therefore toxic. The federal guidance document: *The Metals Translator: Guidance For Calculating A Total Recoverable Permit Limit From A Dissolved Criterion* (EPA

823-B-96-007) has promoted the implementation of water quality criteria for metals which are expressed as dissolved concentrations. These guidance documents are based upon the assumption that it is only the dissolved fraction of metals in surface waters which are bioavailable. In order to set effluent limits based on this dissolved fraction, an assessment must be made to determine the total recoverable concentration in the effluent which corresponds to the fraction of discharged metal that will be available in the dissolved form under ambient chemical conditions. It must be noted that dissolved is defined as filtrable (filtrable at 0.4 to 0.45 µm pore size, ss. NR 105.05(5) and 105.06(8), Wis. Adm. Code) and in many instances only a relatively small portion of the filtrable metal is actually dissolved in solution. The process that follows is a mechanism by which existing total recoverable criteria can be converted to water quality criteria expressed as a dissolved concentration (dissolved criteria) and adjusted to account for the degree to which the ambient water chemistry will render a portion of the discharged metal to be less bioavailable. Water quality based effluent limitations can then be calculated based upon the dissolved criteria.

This guidance is consistent with the following federal guidance document: *The Metals Translator: Guidance For Calculating A Total Recoverable Permit Limit From A Dissolved Criterion* (EPA 823-B-96-007). The federal guidance recommends generating a translator using one of the following three methods: "(1) It may be assumed to be equivalent to the criteria conversion factors. (2) It may be developed directly as the ratio of dissolved to total recoverable metal. (3) Or it may be developed through the use of a partition coefficient that is functionally related to the number of metal binding sites on the adsorbent in the water column (i.e., concentrations of TSS, total organic carbon, or humic substances). The department approach for calculating a total recoverable permit limit from a dissolved criterion contains a method which is functionally equivalent to option number (2) above. Implementation of option number (1) results in no numerical difference between application of total recoverable criterion and dissolved criterion and is a broad, very conservative estimate. Implementation of option number (3) is perhaps more scientifically accurate but is data intensive and difficult to implement on a large (statewide) scale.

Water Quality Criteria:

To implement water quality criteria expressed as dissolved concentrations, adjustments to the water quality criteria in ch. NR 105, Wis. Adm. Code must be made as described in ss. NR 105.05(5) and NR 105.06(8), Wis. Adm. Code, before calculating a WQBEL. Only acute and chronic toxicity criteria can be expressed in the dissolved form. In general, assumptions must be made to determine the ability of a receiving water to render a portion of discharged metal non-bioavailable. Because the purpose of this process is to account for site-specific characteristics which render a portion of the discharged pollutant less bioavailable in the receiving water, the parameters used to translate the criteria should be representative of the receiving water. There is no difference in the way in which the conversion and translation should occur for acute and chronic criteria.

Conversion and Translation

To adapt a total recoverable criterion into a dissolved criterion, two adjustments are needed: conversion and translation. First, the total recoverable criterion must be converted to a dissolved criterion according to ss. NR 105.05(5) and NR 105.06(8), Wis. Adm. Code.

$$WQC_D = (CF)(WQC_{Total\ R})$$

Where:

$WQC_{Total\ R}$ = Criterion from ch. NR 105, Table 5 or 6

CF = Conversion factor for total recoverable to dissolved

The conversion factor simply represents that percentage of metal which was dissolved in the laboratory water in the toxicity tests used for criteria generation. Since the solids concentration is very low in laboratory water, the conversion factors are less than but very close to 1.0. Conversion factors are as follows:

	Acute	Chronic
Arsenic	1.000	1.000
Cadmium	0.850	0.850
Chromium (III)	0.316	0.860
Chromium (VI)	0.982	0.962
Copper	0.960	0.960
Lead	0.875	0.792
Mercury	0.850	0.850
Nickel	0.998	0.977
Selenium	0.922	0.922
Silver	0.850	N/A
Zinc	0.978	0.986

TABLE 6: CONVERSION FACTORS FOR DISSOLVED CRITERIA FROM SS. NR 105.05(5) AND 105.06(8), WIS. ADM. CODE

Second, the dissolved criterion (converted from total recoverable) needs to be "translated". The magnitude of the translator reflects the ability of the receiving water to render a portion of the discharged metal non-bioavailable in the receiving water. The translation involves multiplying the criterion resulting from the first step by a translator which will account for site-specific conditions.

$$WQC_{TRAN} = (Translator)(WQC_D)$$

The translator consists of a ratio indicating how much discharged metal will be less bioavailable after discharge to a surface water from ss. NR 105.05(5)(b) and NR 105.06(8)(b), Wis. Adm. Code. In order to generate the translator, the following data are needed:

1. Total Suspended Solids - TSS (site-specific receiving water or appropriate surrogate) in grams per liter (see discussion on TSS). Note: TSS data are often reported as milligrams per liter, however, the equation for generating a translator requires that TSS data be expressed as grams per liter.

2. Particle bound concentration of metal, expressed as micrograms of metal per gram of particulate matter (µg metal/gram solids). The particle-bound concentration of metal should either be site-specifically determined or an appropriate default used. If site-specifically determined, annual or semi-annual (minimally) monitoring of total recoverable metal, dissolved metal, and TSS is recommended. Particulate metal concentration is calculated by subtracting the dissolved metal concentration from the total recoverable metal concentration. Therefore, to obtain M_P from site-specific data of total recoverable and dissolved metals measurements in the receiving water, the following calculation is recommended:

$$M_P = \frac{M_{TR} - M_D}{\mathrm{TSS}}$$

Where:

M_P, = Particulate bound metal concentration (µg/g)
M_{TR}, = Total Recoverable metal concentration (µg/L)
M_D = Dissolved metal concentration (µg/L)
TSS = Total Suspended Solids (g/L)

Appendix C contains particulate-bound metal concentrations that may serve as acceptable default data.

3. Filtrable (dissolved) concentration of the applicable metal in the receiving water, expressed as micrograms of metal per liter of water (µg metal/liter water). If site-specifically determined, annual or semi-annual (minimally) monitoring of the filtrable metal in the receiving water is recommended to accurately characterize it. However, this number has much less significant impact on the magnitude of the translator, so it may not warrant specific determination in all cases. Appendix C contains "total recoverable" and "dissolved" metals concentrations for multiple sites throughout Wisconsin that may serve as acceptable default data.

If it is unclear as to which data should be used for translation (TSS, M_p, and M_d), persons with local/stream expertise should be consulted, such as a regional water quality biologist.

Use of Total Suspended Solids (TSS) Data in Translator Development:

The concentration of TSS in the receiving water is a critical component of the generation of the translator. Generally, the magnitude of the translator is a function of the TSS concentration. As TSS increases, the number of "binding sites" increases for discharged heavy metals. Caution must be taken to select a conservatively low TSS value so the receiving water does not violate standards for a portion of the year. If an inaccurately high TSS value is used, the developed translator will not be representative and more metal than expected will be bioavailable. TSS has been measured for many streams and lakes and much data exists in SWIMS and other similar databases. These data may be acceptable for use in translator development, however, caution should be taken to ensure that data were not collected during stormwater or agricultural runoff events, in which case it will likely be quite high and not representative of the typical solids concentration in the receiving water. Receiving water TSS data collected by the facility may also be used, if proper collection methods were used.

A seasonal pattern or trend may be apparent if sufficient data are available. Once data are collected and tabulated, obtaining the geometric mean of all the sample results is an acceptable means to arriving at a number to use for the translator. If all of the available data were collected during stormwater or agricultural runoff events and the concentrations are elevated, other data should be sought, and/or the facility may be asked to collect data that is more representative of normal conditions. In some cases, a subset of existing data may suffice for translator development. Since collection of TSS data is not expensive, a facility may wish to collect additional data in order to calculate a more accurate and representative translator. If a strong seasonal pattern is observed, a TSS number which represents a time when TSS are expected to be lower may be appropriate to protect the surface water when available binding sites for metals are minimal. In addition, the common limit of detection for TSS is commonly in the range of 2 mg/L. If a stream is sampled at a time when TSS are expected to be lower, such as base flow, winter, etc., TSS should be measured using an analytical method with a lower level of detection (LOD). Typically, achieving a lower LOD simply means filtering a larger sample (volume) of water.

Calculation of Dissolved Metals Translator Using Site-Specific Data:
Data on dissolved and particulate metals from a nearby site may be used to obtain a dissolved-based criterion that accounts for site-specific conditions using the procedure in s. NR 105.05(5), Wis. Adm. Code:

$$Translator\ (unitless) = \frac{(M_P)TSS + M_D}{M_D}$$

Substituting the particulate bound metal concentration formula for M_P into the Translator formula, we obtain:

$$Translator\ (unitless) = \frac{\left(\frac{M_{TR} - M_D}{\mathrm{TSS}}\right)TSS + M_D}{M_D}$$

Simplifying, we have:

$$Translator\ (unitless) = \frac{\left(\frac{M_{TR}}{\mathrm{TSS}}\right)TSS - \left(\frac{M_D}{\mathrm{TSS}}\right)TSS + M_D}{M_D} = \frac{M_{TR} - M_D + M_D}{M_D} = \frac{M_{TR}}{M_D}$$

Using the translator and WQC_D, the procedures in s. NR 106.05, Wis. Adm. Code, can be applied to WQC_{TRAN} to determine reasonable potential. The conditions and requirements from this outcome are given in s. NR 106.06(7)(b), Wis. Adm. Code.

If reasonable potential to exceed limits based on WQC_{TRAN}, is shown, then the limitations, the monitoring conditions in s. NR 106.06(7)(c)1., Wis. Adm. Code, and the source reduction requirements of s. NR 106.06(7)(c)2., Wis. Adm. Code, shall be included in the permit.

If reasonable potential to exceed limits based on WQC_{TRAN}, is not shown, then no limitations shall be established, but the monitoring conditions in s. NR 106.06(7)(c)1., Wis. Adm. Code, shall be included in the permit.

Monitoring Requirements

The following types of monitoring may be applicable to facilities considering or implementing dissolved based WQBELs:

1. **Effluent:** When analysis of the applicable metal in effluent in total recoverable and filtrable (total dissolved) form is required in the permit, grab samples should be taken at least four months apart with total recoverable (unfiltered) metal using low-level methods if it is likely that routine analysis will result in un-reliable data or "less than" detection results. Low level sampling and analysis required should be completed by a certified lab. Sampling methodology shall to be consistent with EPA Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels. Sample analysis should be consistent with EPA Method 200.8: Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectrometry or a method that provides equivalent sensitivity. Collection of samples should occur during base flow conditions, when no stormwater runoff events are taking place. These samples should be collected concurrently with a monthly or quarterly effluent sample collected for the metal or hardness, respectively. If 24-hour composite sampling is required for compliance, and low level grab sampling is required for the purpose of translator generation, it is possible that some sampling duplication would result. Grab sampling is preferred due to the inherent problems associated with obtaining contaminant-free samples using composite samplers.

2. **Receiving Water:** When analysis of the applicable metal in the receiving water in total recoverable and filtrable (total dissolved) form is required in the permit, grab samples are preferred. Low-level metals sampling and analysis should generally be required to accurately characterize the metal in the receiving water. Sampling should occur in an area which is representative of the mixed receiving water and effluent (at whatever point chemical equilibrium has been reached). If site-specific data for a conservative (non-degradable) substance/parameter such as conductivity are available, these data could be used to quantitatively determine the point of chemical equilibrium. However, if this data is unavailable, a qualitative determination may be allowable to determine the point of complete mixing. If total recoverable, filtrable, and total suspended solids data are collected, the translator which was used for calculation of the effluent limit can be verified. Obtaining total suspended solids information will provide a means to check the validity of the translator which was used to generate the effluent limit. The exact location will depend upon the hydrologic characteristics (mainly flow) of the effluent and receiving water. Monitoring frequency should be set on a case-by-case basis but generally should not exceed quarterly sampling/analysis.

3. **Sediment:** Analysis of downstream sediments for the applicable metal in total or total recoverable form (may depend on the metal) may be required. Sediment monitoring should only be imposed if there is a concern about deposition of metal-laden particles in a zone downstream of a discharge. Sediment monitoring plans cannot be implemented as a fixed approach, because there are

many variables and differences between discharge sites. The permit drafter and/or limit calculator should use local expertise and their best professional judgement and work with appropriate department staff such as contaminated sediments staff in the Office of Great Waters or Remediation and Redevelopment programs to determine prudent sediment monitoring provisions.

The sampling location should be in an area which represents the closest depositional area downstream of the outfall. The sample(s) should be collected from the top section of the sediment to represent recently deposited material. If grab sampling is performed, recently deposited material will automatically be collected. If coring is done, the top 10 cm will generally represent recently deposited material. Frequency should be determined case specifically but generally should not exceed semi-annual sampling/analysis. Applicability of sediment sampling is a function of stream flow to effluent flow (Q_s:Q_e) ratio and the presence and/or proximity of a depositional area. Sediment monitoring may be necessary in situations where areas in close proximity to the discharge are thought to be receiving a sediment load contaminated with metals. If staff have reason to believe that there is an area susceptible to accumulation of sediments laden with metals from a specific discharge, sediment monitoring should be required.

If it is found that a depositional zone is being loaded with heavy metals, the limit calculator may need to alter the applicable translator or re-examine a less stringent effluent limitation that was previously calculated using dissolved criteria. Due to the complexities of deposition, a trend in deposition and loading to an area would need to be established to link the deposition to the applicable discharger. Depending on the characteristics of the site, it may be useful for the discharger to obtain upstream sediment data. For example, if there are many other dischargers in the area, the facility may need to collect information immediately upstream of their facility to rule out other sources for the deposited metal-laden sediments.

Receiving Water Monitoring Recommendations: If a WPDES permit contains a dissolved metals effluent limit, the receiving water should be monitored for total recoverable and filtrable metal, and total suspended solids. At least semi-annual grab samples obtained during summer and winter months (or at least low flow) using low-level sampling and analysis techniques. Commercial laboratories are available for this work. As discussed above, samples should be taken from an area which is representative of effluent and receiving water. Total recoverable and dissolved (filtered and unfiltered) metal should be measured. Effluent to receiving water ratios may also be factor in frequency, as discussed above. TSS results should also be obtained from the same time periods at the same location. TSS data are important for translator development/confirmation. Possible exceptions to this monitoring frequency are described below. Effluent monitoring should occur for total recoverable and dissolved metal at least annually with increased frequency as described below, or as otherwise deemed necessary due to variability, etc.

<u>Stream flow to effluent flow (Q_s:Q_e) ratio as applied to effluent and receiving water monitoring:</u> For high Q_s:Q_e ratio situations, or obvious stream-dominated flow regimes, annual or semi-annual monitoring should suffice for assessing significant changes in receiving water or effluent quality. For low Q_s:Q_e ratio

situations, or obvious effluent-dominated flow regimes, quarterly monitoring may be necessary to characterize the concentrations or other important aspects of the site. If the Q_s:Q_e ratio does not allow a clear determination of the effluent and receiving water characteristics, the determination for monitoring frequency should be based on other factors such as surface water classification, magnitude of the translator, or other objective criteria. If the applicable translator is above a value of approximately three to five, the calculated effluent limit may be quite elevated with respect to the limit as calculated from a total recoverable water quality criterion.

<u>In-stream total suspended solids (TSS) concentration:</u> If in-stream TSS is high, a large translator may have been applied in the generation of the effluent limit. If TSS is elevated during some portion of the year (approximately greater than 50-100 mg/L) quarterly monitoring for effluent and/or receiving water may be appropriate. If TSS is low or moderate (approximately 10-50 mg/L), annual, semi-annual, or tri-annual monitoring may be warranted. For sediments, as the concentration of TSS increases the potential for deposition may also increase, especially if an impoundment is nearby downstream. In situations like these, sediment monitoring may be warranted. If TSS is low, and an impoundment or depositional area is located nearby, sediment monitoring may be required on an annual basis, or, if TSS is elevated in the receiving water and an impoundment is nearby, semi-annual monitoring should be required. If it is apparent that sediment deposition will not occur to a significant extent either due to low TSS, high Qs:Qe ratio, or other factors which indicate that insufficient solids are present to deposit, no sediment monitoring should be required.

<u>Presence/location of impoundment or apparent depositional zone:</u> If a facility receives an effluent limit based upon a dissolved water quality criterion and the outfall is in reasonably close proximity to an impoundment or apparent depositional area, an increased probability of particulate-phase metals deposition increases. If a depositional area is nearby, annual sediment monitoring for the applicable metal may be warranted. If the receiving water is low in TSS and the facility does not contribute significant solids to the receiving water, then sediment monitoring in a depositional area may not be necessary.

Monitoring is necessary due to uncertainty of quantifying fate, transport, and bioavailability of heavy metals in receiving waters. The behavior of metals in surface waters is complex and dynamic. While the default procedure is useful in determining the probable fate of a discharged metal, site-specific monitoring may produce data more suitable for use in verifying the applicable translator. Depending upon circumstances such as the calculated effluent limitation, magnitude of the translator, specificity of the data which produced the translator (or lack thereof), and local site conditions, a translator (and resulting effluent limitation) could be modified during a permit or at reissuance. Monitoring conducted during the permit term may be used to check the magnitude of the translator applied to the water quality criterion, to ensure that effluent toxicity is not occurring, and to confirm that sediments are not subject to increased deposition of metal-laden particles.

Source Reduction Requirements to Accompany a Dissolved-based Effluent Limit:
The intent of a facility performing source reduction measures is to minimize unnecessary heavy metals discharge. If a facility receives an effluent limit based upon the dissolved water quality criterion, then the facility should ensure that they will only discharge that portion that they cannot reasonably treat in accordance with s. NR 106.06(7)(c)2., Wis. Adm. Code. Information on developing a Source Reduction Measures plan and implementing it can be found in the 2020 guidance document: *Development and Implementation of Water Quality Standards Variances* (DRAFT).

Section 6.6: Cumulative Toxicity Evaluations

Cumulative Cancer Risk
Table 9 in ch. NR 105, Wis. Adm. Code lists water quality criteria for protection from human cancer risk. If limits are triggered for more than one human cancer criteria, the incremental risk of each carcinogen detected should be assumed to be additive (s. NR 106.06(8), Wis. Adm. Code) and the toxicity equivalence factor (TEF) in the effluent should be evaluated.

$$TEF = \frac{effluent\ concentraiton}{human\ cancer\ effluent\ limit}$$

If the sum of all the toxicity equivalence factors is greater than one, alterations to the limits will be needed. Section NR 106.06(8), Wis. Adm. Code requires that the TEF sum be limited to one, but it does not specify how exactly to implement this requirement in permits. The following approach is generally recommended, but alternate approaches may be appropriate depending on the situation.

$$\sum TEF \leq 1, \text{ no reasonable potential}$$

If limits are needed for more than one carcinogen, individual limits for each compound should be established so that the total TEF when added together is not greater than one. The limit for each substance should be reduced from the WQBEL proportionally using the equation below. TEF only needs to be calculated for substances that trigger a limit based on human cancer criteria.

$$Adjusted\ WQBEL = WQBEL \times \frac{1}{TEF}$$

Halomethanes and Technical Grade BHC
Chapter NR 105, Wis. Adm. Code, includes criteria for halomethanes and technical grade BHC, which are not single compounds, but a sum of compounds**.** When assessing the need for limits on halomethanes or technical grade BHC, the representative effluent concentrations are the sum of the detected results for the component compounds. (Non-detect results are substituted with zero.)

Halomethanes include:

Bromomethane (methyl bromide)

Chloromethane (methyl chloride)
Tribromomethane (bromoform)
Bromodichloromethane (dichloromethyl bromide)
Dichlorodifluoromethane (fluorocarbon 12)
Trichlorofluoromethane (fluorocarbon 11)

(Table 9 in ch. NR 105, Wis. Adm. Code)

Technical grade BHC (benzene hexachloride) is a mixture of several forms of BHC which was once used as an insecticide in the United States. To be conservative, the technical BHC concentration should be estimated as the sum of the following component substance measurements:

Alpha-BHC
Beta-BHC
Gamma-BHC
Delta-BHC

Chapter 7 – Pollutant Types: Conventional Pollutants

Chapters 1 through 5 covered the general process for determining applicable water quality criteria, calculating WQBELs and determining if WQBELs should be included in the permit. This chapter covers how these processes differ for conventional pollutants and exceptions or special considerations for specific pollutants.

Conventional pollutants refer to pollutants considered to be treatable by a municipal sewage treatment plant. The substances covered in this chapter may be limited by either WQBELs, categorical limits, or both. The focus of the discussion will be on determination of WQBELs.

Section 7.1: Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO)

Water quality standards for dissolved oxygen in surface waters are listed in s. NR 102.04(4), Wis. Adm. Code. This section sets a minimum dissolved oxygen (DO) level of 5.0 mg/L for all fish and aquatic life waters except for cold waters which have varying dissolved oxygen criteria depending on site specific conditions (s. NR 102.04(4)(b), Wis. Adm. Code). The limits in WPDES permits must ensure that DO water quality criteria are met in the receiving water.

One component of this is maintaining a sufficient level of DO in the discharged effluent. The other component is limiting the discharge of substances which will exert oxygen demand on the receiving water in the days following discharge. In wastewater, the sum of these oxygen demanding substances is measured and limited in the form of five-day biochemical oxygen demand (BOD_5) measurements. WQBELs for BOD_5 are needed when the calculated limits are more stringent than categorical BOD_5 limits.

In summary, Wisconsin does not have water quality criteria for BOD itself but limiting discharge levels of BOD is necessary to ensure that WQC for dissolved oxygen are met.

This section discusses the department recommended procedures for establishing BOD_5 and DO limitations that satisfy the provisions of chs. NR 102, NR 104, and NR 210, Wis. Adm. Code. There is not set procedure in administrative code for calculating BOD WQBELs but the following guidance for calculating limits may generally be followed. For background, Table 7 provides a summary of the different possible types of BOD limits that may be included in permits. Figure 4 is a flow chart to help determine which of these limits would be applicable in a given situation.

Limit Category	BOD_5 Limit Type	Reference	Recommended or Required Value	Discharges that limits may apply to	Corresponding CBOD limits
LAL	Categorical	NR 104, 210	LAL: 20 mg/L monthly avg and 30 mg/L weekly avg	Discharges to LAL waters	16 mg/L monthly avg and 25 mg/L weekly avg
LFF			LFF: 15 mg/L monthly avg and 30 mg/L daily max	Discharges LFF waters	12 mg/L monthly avg and 25 mg/L daily avg
Municipal Categorical (30/45)	Categorical	NR 210	30 mg/L monthly avg and 45 mg/L weekly avg	Municipal discharges	25 mg/L monthly avg and 40 mg/L weekly avg
Industrial Categorical	Categorical	NR 225, 240, 284	Mass limits often accompanied by BPJ concentration limits	Certain industries	N/A
WQBEL	WQBEL	Section 7.1 of this guidance	Calculated - between 5 mg/L and the categorical limit, weekly avg	All discharges	N/A
Minimum 5/10	WQBEL	Section 7.1 of this guidance	10 mg/L winter and 5 mg/L summer, weekly avg with 7.0 mg/L min DO limit	Municipal discharges	N/A

TABLE 7: TYPES OF BOD PERMITS LIMITS

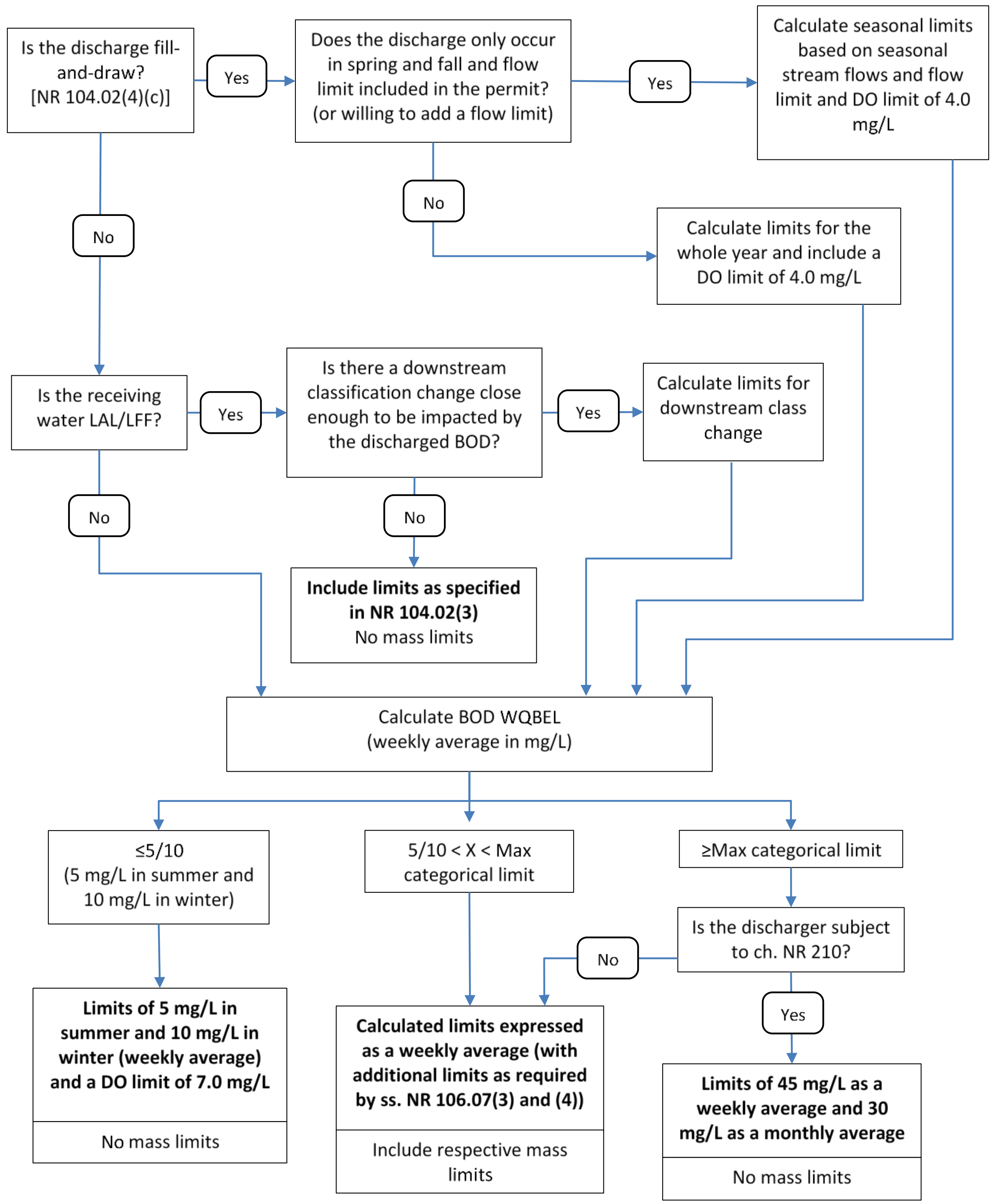


FIGURE 4: FLOW CHART FOR DETERMINING APPLICABLE BOD LIMITS

BOD WQBEL Calculation Methods

The two BOD modeling procedures most often used to calculate BOD WQBELs are the 26-pound method and the Streeter-Phelps Model. Both of these approaches are summarized below. The 26-pound method uses data from a few large rivers and makes several broad assumptions about deoxygenation rates. The Streeter-Phelps model uses more stream-specific information and is typically a more accurate model. However, in order to use this model site-specific information most often needs to be collected by the permittee. Other models may also be used to calculated BOD limits, if deemed appropriate by the department.

Since site-specific information is usually not available to use a more detailed model, the 26-pound method is more commonly used to calculate BOD WQBELs. The Streeter-Phelps model may be used if the required information is available or the permittee will collect this information.

26-Pound Method:
This simplified model relating DO changes to BOD levels was developed in the 1970s by the Wisconsin Committee on Water Pollution on the Fox, Wisconsin, Oconto, and Flambeau Rivers. Further experience throughout the 1970s proved this model to be relatively accurate. This model is used by the department by default where no water quality model has been developed and is the most frequently used approach for calculating BOD limits.

The 26-pound method relates the allowable effluent BOD_5 level to the design flow of the treatment facility and the 7-Q_{10} of the receiving water. This formula is a generalized model based on a few assumptions. The name comes from the approximation that 26 lbs of BOD_5 per day per cfs of receiving water will result in a 2.0 mg/L drop in DO in the receiving water. But the equation can be used to calculate different drops in dissolved oxygen and different temperatures as well.

The formula for calculating limits based on the 26-pound method is as follows:

$$Weekly\ Average\ Limit = \frac{2.4 \times (DO_{mix} - WQC) \times (7Q_{10} + Q_e) \times 0.967^{T-24}}{Q_e}$$

Where:

- DO_{mix} = DO concentration of effluent mixed with receiving water
- WQC = Water quality criterion for dissolved oxygen,
- $7Q_{10}$ = Seven-day 10-year low flow for the receiving water in cfs
- Q_e = Effluent flow in cfs
- T = Stream temperature in degrees C

The 2.4 multiplier comes from converting the units of the 26 lbs BOD_5 per 2.0 mg/L DO per cfs per day estimate:

$$\frac{26\ lbs\ BOD_5}{2.0 \frac{mg}{L} DO \cdot day \cdot cfs} \times \frac{1\ day}{86400\ sec} \times \frac{453592\ mg}{1\ lb} \times \frac{1\ ft^3}{28.32\ L} = 2.4$$

In the absence of monitoring results, effluent and receiving water DO concentrations are typically assumed to be 5.0 mg/L and 7.0 mg/L, respectively. Facility and site-specific data for dissolved oxygen and temperature should be utilized when available. Seasonal dissolved oxygen data may also be considered if the differences or the effect on the limitations are significant. Data from the lowest-flow period of the season is ideal since limits are based on low flow conditions.

A facility can receive higher BOD limits if the effluent dissolved oxygen level is higher than the assumed 5.0 mg/L. If BOD limits are calculated assuming an effluent dissolved oxygen level that may not be readily attainable or requires post-treatment aeration to meet, a minimum DO limit should be included in the permit to ensure that this level is maintained.

When determining the estimated DO_{mix}, the saturation DO concentration at stream conditions should be considered. The use of a DO_{mix} should not result in a DO_{mix} that exceeds saturation levels. This is primarily a warm-weather issue, since the DO saturation level decreases at higher temperatures. Note that the DO saturation level at 25ºC is 8.24 mg/L. Considering this, 7.0 mg/L is a conservative estimate for maximum DO in summer but DO levels may be higher in winter if conditions permit.

Flow-Related Limits:
In place of the conservative assumptions of effluent and stream flow rates, a facility may instead opt for flow-related BOD limits. In place of a single estimate of stream low flow and facility design flow, the BOD limits would be based on the actual daily stream flow to effluent flow ratio (Q_s:Q_e). For flow related limits to be appropriate, the facility should have the ability to accurately measure stream and effluent flow rates during discharge periods. The permittee should maintain a stream gauge which is properly calibrated at least once a year and is able to accurately measure effluent flow rates.

BOD limits can also be based on monthly or seasonal low flows if they are available. The limit calculation should also factor in seasonal temperature changes and known changes in DO.

Streeter-Phelps Model:
The Streeter-Phelps model considers changes in DO levels from carbon sources, nitrogen sources, sediment, photosynthesis/respiration, and reaeration. It can be used to determine BOD limits on small streams that will achieve DO standards. The model requires site-specific data and considers the effect of temperature on the reaction rates and the effects of solubility, diffusion, and turbulence on reaeration.

The basic Streeter-Phelps oxygen sag equation is:

$$D = \frac{K_D L_o}{K_R - K_D} \times (e^{-K_D t} - e^{-K_R t}) + D_o e^{-K_R t}$$

Where:

D_o = initial DO saturation deficit of the water in mg/L
D = saturation deficit of DO at time t

L_o = ultimate biochemical oxygen demand (BOD_u) of the at the point of discharge in mg/L
K_D = deoxygenation coefficient
K_R = reaeration coefficient
t = elapsed time in days

In order to develop a water quality model, at least two water quality studies should be performed at each discharge point of standards application. The first study should calibrate the input data and the second should verify the model. The studies should be performed as close to low flow conditions as possible. This approach is time-consuming, often requiring six months from initial study to completion of the model summary.

Minimum BOD WQBELs

It is recommended that the lowest concentration limits given for BOD_5 be 5 mg/L in May-October and 10 mg/L in November-April, expressed as a weekly average concentration limit, and that total suspended solids limits not be set lower than 10 mg/L, expressed as a monthly average concentration limit year-round. Additionally, when BOD_5 and TSS limits are set to these minimum levels the dissolved oxygen effluent limit should be set at 7.0 mg/L. These recommendations are made based on the perceived inaccuracy of water quality models at lower ranges, the uncertainty that effluent limits below 5 and 10 mg/L can be consistently met, and the associated high cost of treating to meet limits below these levels.

The 5 mg/L and 10 mg/L limits are approximately equal to the limits calculated using the 26-lb method when assuming a DO drop of 2 mg/L. With instream DO of 7.0 mg/L and DO criteria of 5.0 mg/L, the 7.0 mg/L effluent DO limit ensures that at least a 2 mg/L drop in DO can occur while still ensuring that water quality criteria are met in the receiving water.

When these minimum limits are given in a permit, no BOD_5 mass limits are needed.

LFF and LAL BOD Limits

The BOD limitations for receiving waters classified as either limited forage fish communities or limited aquatic life are established under ss. NR 104.02(3)(a) and (b), Wis. Adm. Code, respectively. These limitations apply for all streams classified under this section, unless the discharge may cause downstream reaches with a different classification to be impacted to a point where water quality standards would not be met. In those situations, the BOD limitations should be calculated using a model or the 26-lb method based on downstream water quality criteria.

Fill and Draw

For fill and draw discharges to limited aquatic life and limited forage fish streams, s. NR 104.02(4)(c), Wis. Adm. Code, allows limits different than those specified in Tables 1 and 2 of ch. NR 104, Wis. Adm. Code, for these stream classifications. In these cases, a minimum DO limit of 4.0 mg/L is required and limits must not exceed the assimilative capacity of the receiving water. In order to allow limits higher than those for LFF and LAL waters, it must be demonstrated that the discharge would not cause non-attainment of water quality criteria in any downstream waters.

If the discharge only occurs in spring and/or fall, low flows for these months of the year may be used instead of annual low flow estimates. In these cases, the permit should include a requirement to only discharge during the applicable months. For seasonal dischargers, the typical method for calculating mass limits may not be appropriate since it assumes year-round discharge. The mass limit may be calculated using an effluent flow rate that is consistent with an average flow rate during discharge periods (not including days of no discharge in the average flow calculation).

If a specific flow rate lower than the design flow rate is used in limit calculations, the permit should include a flow limit at this level.

Dissolved Oxygen Limits

Along with BOD_5 limits, DO limits are recommended when:

- Discharging to an LAL or LFF receiving water (dissolved oxygen level specified in ss. NR 104.02(3)(a)2.a and (b)2.a)
- BOD limits are WQBELs calculated using the 26-pound equation or another method, less than the categorical limits of 30 mg/L and 45 mg/L, set equal to the effluent level assumed in WQBEL the calculation.
- Limits are set at the 5 mg/L and 10 mg/L minimum BOD WQBEL discussed on Page 69. A DO limit of 7.0 mg/L is recommended to be protective of water quality standards.

DO limits are not required when:

- BOD limits are based on the categorical standards in s. NR 210.05(1)(a), Wis. Adm. Code (30 mg/L and 45 mg/L limits for municipal dischargers)

Mass limits

Mass limits are important for antidegradation purposes and limiting the total use of assimilative capacity. If the effluent concentration limit is the only limit in the permit and then the effluent volume increases above the expected level, the total mass discharged could result in exceedance of the acceptable assimilative capacity. Mass limits are also important for marking the current discharge pollutant loading for antidegradation purposes. If a facility increases its BOD loading to the receiving water, it should be considered an increased discharge under ch. NR 207, Wis. Adm. Code.

For BOD, mass limits are typically included in WPDES permits when the concentration limits are based on a WQBEL calculation. No mass limits are needed if the concentration limits required are for LAL or LFF waters as in s. NR 104.02(3), Wis. Adm. Code, the categorical limits in s. NR 210.05(1), Wis. Adm. Code, or if limits are set at the minimums of 5 mg/L and 10 mg/L. This is because when there is low or no dilution, concentration limits change very little as effluent flow rate changes. This means that changes in effluent flow rates do not result in the use of significantly more assimilative capacity, so the concentration limit should be sufficiently protective of water quality without mass limits. When WQBELs are being set for discharges to higher flowing waters, mass limits are included to ensure that any increased discharge rates do not result in a lowering of water quality without consideration of antidegradation.

Carbonaceous Biochemical Oxygen Demand (CBOD)

Categorical CBOD WQBELs

Section NR 210.05, Wis. Adm. Code allows for categorical BOD limits to be substituted with categorical CBOD limits if the monitoring required by s. NR 210.07(4)(a), Wis. Adm. Code is provided. If substituted, the alternate CBOD limits are outlined in s. NR 210.05 (1) (d), (2) (f), or (3) (e), Wis. Adm. Code, and summarized in Table 7.

Total BOD is approximately equal to CBOD plus NBOD (nitrogenous oxygen demand). To account for the amount of the total BOD that results from nitrification, the CBOD limits outlined in ch. NR 210 are set lower than the corresponding BOD limits.

If a facility requests categorical CBOD limits, department staff should consider the paired BOD and CBOD data provided in accordance with NR 210.07(4), Wis. Adm. Code. If effluent CBOD levels are significantly lower than BOD levels, and it appears that the discharge will be able to meet the applicable CBOD limits listed in s. NR 210.05, Wis. Adm. Code, substituting CBOD limits for BOD limits is appropriate.

CBOD WQBELs

The department does not recommend CBOD WQBELs in WPDES permits because of the distinction between reasons for including BOD WQBELs and BOD categorical limits in permits (see discussion above). Categorical limits for BOD are based on the expected performance of biological treatment technology to remove organic materials and solids which can degrade through biological processes. BOD WQBELs, on the other hand, are set only to ensure that dissolved oxygen criteria are met in the receiving water and do not consider the effectiveness of the treatment system.

This difference is important when considering CBOD limitations. When considering categorical limits, the NBOD portion of the total BOD is not of concern, since this part of BOD is not directly related to the ability of the treatment system to remove organic solids. For WQBELs however, the NBOD portion is just as important as the CBOD portion since both quantify the effluent oxygen demand on the receiving water.

For this reason, any WQBEL limits for CBOD would need to account for NBOD in order to be protective of water quality. A protective CBOD WQBEL would equal the BOD WQBEL minus the ultimate NBOD. In most cases, this would result in a CBOD limit that is more restrictive than the original BOD WQBEL, and therefore CBOD WQBELs are generally not recommended.

Section 7.2: pH

Water quality criteria for pH in fish and aquatic life waters are given in s. NR 102.04(4)(c), Wis. Adm. Code:

> *"The pH shall be within the range of 6.0 to 9.0, with no change greater than 0.5 units outside the estimated natural seasonal maximum and minimum."*

Unlike most pollutants with water quality criteria, pH does not behave conservatively, and it is not appropriate to calculate limits using a mass balance method. Therefore, permits generally include a minimum pH limit of 6.0 and a maximum pH limit of 9.0 to ensure that these criteria are met in the receiving water. Exceptions to this are allowed for paper mills in accordance with ch. NR 284, Wis. Adm. Code, and industries which monitor pH continuously in accordance with s. NR 205.06, Wis. Adm. Code, where it has been determined that sufficient dilution is available to ensure that pH water quality criteria are met. These limits should be consistent with the effluent limitations applicable to the category of dischargers to which the industrial point source belongs.

Section 7.3: Total Suspended Solids (TSS)

Total Suspended Solids WQBELs are included in permits where BOD_5 WQBELs are being given, in order to ensure compliance with the narrative water quality criteria in s. NR 102.04(1)(a), Wis. Adm. Code, that requires that discharges do not contain substances that will cause objectionable deposits on the shore or in the bed of the waterbody. TSS limits are generally set equal to BOD limits with a minimum TSS limit of 10 mg/L as recommended in Section 7.1.

Categorical TSS limits for municipalities are included in ch. NR 210, Wis. Adm. Code, and for industry in chs. 220-299. Industrial dischargers may have other permit limits set by best professional judgment. Section NR 210.07(2) allows for aerated lagoons and stabilization ponds to receive a higher categorical TSS limit of 60 mg/L expressed as a 30-day average.

Chapter 8 – Expression of Limits

In order to comply with federal regulations in 40 CFR 122.45(d), ss. NR 106.07(3) and (4), Wis. Adm. Code, requires, whenever practicable, that effluent limitations be expressed as:

- Weekly average and monthly average limitations for continuous discharges subject to ch. NR 210, publicly owned treatment works and privately-owned domestic sewage treatment works
- Daily maximum and monthly average limitations for other continuous discharges (industries).

These requirements apply to:

- Concentration limits for toxic and organoleptic compounds based on criteria in ch. NR 105, Wis. Adm. Code. (ss. NR 106.07(3) and (4))
- Concentration limits for conventional pollutants including BOD and TSS (s. NR 205.065(7), Wis. Adm. Code.)

The requirements of 40 CFR 122.45(d) apply only to final water quality based effluent limitations. Therefore, the requirement for additional limits does *not* apply:

- To non-continuous discharges which do not meet the definition of "continuous discharge" in s. NR 205.03 (9g), Wis. Adm. Code.
- To variance limits or other interim limits
- To mass limits (other than TMDL mass limits)
- Where the expression of limits for an averaging period is considered to be "impracticable" (s. NR 106.07(10), Wis. Adm. Code)
- To categorical limits such as:
    - Weekly and monthly average limits for discharges to limited aquatic life waters in s. NR 104.02(3), Wis. Adm. Code.
    - Daily maximum and monthly average limits for discharges to limited forage fish waters in s. NR 104.02(3), Wis. Adm. Code.
    - Daily maximum fecal coliform limit from ch. NR 258, Wis. Adm. Code.

  In these cases, a different averaging period is allowed per s. NR 205.065(7), Wis. Adm. Code, as these limit averaging periods are specified in code.

Daily maximum and weekly average categorical or production-based limitations derived from chs. NR 221 – 299, Wis. Adm. Code, may be used in lieu of the following procedures for converting WQBEL averaging periods if they are applicable. Typically, these limits are calculated as mass limitations.

The procedures for calculating additional limits that are needed to comply with ss. NR 106.07(3) & (4) and 205.065(7), Wis. Adm. Code, are intended to create limits that are not any more restrictive than the original limits required to prevent toxicity and other water quality impacts. Procedures for calculating limits needed to meet expression of limit requirements for discharges subject to ch. NR 210, Wis. Adm.

Code and all other discharges are described below. Expression of limit examples are included in Appendix D.

Impracticability:
The limit expressions of weekly and monthly for municipal discharges and daily and monthly for industrial discharges may not always be appropriate. This could be due to the chemical or physical properties of the pollutant, distribution of effluent data (i.e. whether or not the specific data are lognormal distributed), and effluent variability.

The expression of limits procedures described in this chapter are impracticable for the following pollutants given their unique chemical and/or physical properties:

- pH
- Temperature
- Color
- Alkalinity/Hardness
- Dissolved oxygen
- Flow
- Phosphorus (see impracticability discussion in the NPDES Delegation MOA with EPA)
- Whole Effluent Toxicity

Section 8.1: Dischargers Subject to ch. NR 210

The methods for calculating concentration limitations for continuous municipal discharges (subject to ch. NR 210) are specified in s. NR 106.07(3), Wis. Adm. Code, and are as follows:

- Whenever a daily maximum limitation is determined necessary to protect water quality, a weekly and monthly average limitation shall also be included in the permit and set equal to the daily maximum limit unless a more restrictive limit is already determined necessary to protect water quality.
- Whenever a weekly average limitation is determined necessary to protect water quality, a monthly average limitation shall also be included in the permit and set equal to the weekly average limit unless a more restrictive limit is already determined necessary to protect water quality.
- Whenever a monthly average limitation is determined necessary to protect water quality, a weekly average limit shall be calculated using the following procedure and included in the permit unless a more restrictive limit is already determined necessary to protect water quality:

$$Weekly\ Average\ Limit = Monthly\ Average\ Limit \times MF$$

Where:

MF= Multiplication Factor as defined in Table 8 using CV and n

CV= Coefficient of variation (CV) as calculated in s. NR 106.07(5m)
n= the number of samples per month required in the permit

$$CV = \frac{standard\ deviation}{arithmetic\ mean}$$

CV	n=1	n=2	n=3	n=4	n=8	n=12	n=16	n=20	n=24	n=30
0.1	1.00	1.07	1.10	1.12	1.16	1.17	1.18	1.19	1.20	1.20
0.2	1.00	1.13	1.20	1.24	1.32	1.36	1.39	1.40	1.41	1.43
0.3	1.00	1.19	1.29	1.36	1.49	1.56	1.60	1.63	1.65	1.67
0.4	1.00	1.24	1.37	1.46	1.66	1.75	1.81	1.86	1.89	1.93
0.5	1.00	1.28	1.45	1.56	1.81	1.94	2.02	2.08	2.13	2.18
0.6	1.00	1.31	1.51	1.64	1.95	2.12	2.23	2.30	2.36	2.43
0.7	1.00	1.34	1.55	1.71	2.08	2.28	2.41	2.51	2.58	2.67
0.8	1.00	1.35	1.59	1.76	2.19	2.42	2.58	2.70	2.79	2.89
0.9	1.00	1.36	1.61	1.80	2.27	2.54	2.73	2.86	2.97	3.09
1.0	1.00	1.37	1.63	1.83	2.34	2.64	2.85	3.01	3.13	3.27
1.1	1.00	1.37	1.63	1.84	2.39	2.72	2.95	3.13	3.27	3.43
1.2	1.00	1.36	1.63	1.85	2.43	2.79	3.04	3.23	3.38	3.56
1.3	1.00	1.36	1.63	1.85	2.45	2.83	3.10	3.31	3.48	3.68
1.4	1.00	1.35	1.62	1.84	2.46	2.86	3.15	3.37	3.55	3.77
1.5	1.00	1.34	1.61	1.83	2.46	2.88	3.18	3.42	3.61	3.85
1.6	1.00	1.33	1.60	1.82	2.46	2.89	3.20	3.45	3.66	3.90
1.7	1.00	1.32	1.58	1.80	2.45	2.88	3.21	3.47	3.69	3.95
1.8	1.00	1.31	1.57	1.78	2.43	2.87	3.21	3.48	3.70	3.98
1.9	1.00	1.30	1.55	1.76	2.41	2.86	3.20	3.48	3.71	3.99
2.0	1.00	1.29	1.54	1.74	2.38	2.84	3.19	3.47	3.71	4.00

TABLE 8: MULTIPLICATION FACTOR (S. NR 106.07(3)(E)4, WIS. ADM. CODE)

Note: This methodology is based on U.S. EPA Technical Support Document for Water Quality-based Toxics Control (March 1991). PB91-127415.

In calculating a CV:

- If there are fewer than 10 representative data points, the CV shall be set equal to 0.6.
- Monitoring results less than the limit of detection may be assigned a value of zero.
- A value other than zero may be substituted for results less than the limit of detection (s. NR 106.07(5m)(c), Wis. Adm. Code)
    - if the effluent limitation is less than the limit of detection,
    - after considering the number of monitoring results that are greater than the limit of detection, and
    - if warranted when applying appropriate statistical techniques.

Data should be representative of current effluent conditions. Data points that are not representative should be excluded from the calculation.

If the monitoring frequency is modified in the reissued permit from the current permit, the number of samples per month (n) would change resulting in a different multiplication factor and limit. Therefore, these limits should be reviewed at each permit reissuance.

Section 8.2: Dischargers Not Subject to ch. NR 210

The methods for calculating concentration limitations for continuous industrial discharges (not subject to ch. NR 210, Wis. Adm. Code) are specified in s. NR 106.07(4), Wis. Adm. Code, and are as follows:

- Whenever a daily maximum limitation is determined necessary to protect water quality, a monthly average limitation shall also be included in the permit and set equal to the daily maximum limit unless a more restrictive limit is already determined necessary to protect water quality.
- Whenever a weekly average limitation is determined necessary to protect water quality, a monthly average limitation shall also be included in the permit and set equal to the weekly average limit unless a more restrictive limit is already determined necessary to protect water quality. A daily maximum limitation shall also be included in the permit and set equal to the daily maximum water quality-based effluent limitation calculated under s. NR 106.06, Wis. Adm. Code, or a daily maximum limitation calculated using the following procedure, whichever is more restrictive:

$$Daily\ Maximum\ Limit = Weekly\ Average\ Limit \times DMF$$

Where:

DMF = Daily Multiplication Factor based on CV as defined in Table 9 based on the CV
CV= Coefficient of variation (CV) as calculated in s. NR 106.07(5m), Wis. Adm. Code

CV	DMF
0.1	1.114
0.2	1.235
0.3	1.359
0.4	1.460
0.5	1.557
0.6	1.639
0.7	1.712
0.8	1.764
0.9	1.802
1.0	1.828

CV	DMF
1.1	1.842
1.2	1.849
1.3	1.851
1.4	1.843
1.5	1.830
1.6	1.815
1.7	1.801
1.8	1.781
1.9	1.751
2.0	1.744

TABLE 9: DAILY MULTIPLICATION FACTOR (S. NR 106.07(4)(E), WIS. ADM. CODE)

- Whenever a monthly average limitation is determined necessary to protect water quality, a daily maximum limit shall be calculated using the following procedure and included in the permit unless a more restrictive limit is already determined necessary to protect water quality:

$$Daily\ Maximum\ Limit = Monthly\ Average\ Limit \times MF$$

Where:

MF= Multiplication factor as defined in Table 8

CV= Coefficient of variation (CV) as calculated in s. NR 106.07(5m), Wis. Adm. Code

n= Number of samples per month required in the permit

Code	Limitation Needed based on Reasonable Potential			Limitations to be included in WPDES permits for ch. NR 210 dischargers (Municipal Treatment Plants)			Limitations to be included in WPDES permits for all other continuous dischargers		
	Acute	Chronic	Human Health/ Wildlife	Daily Maximum	Weekly Average	Monthly Average	Daily Maximum	Weekly Average	Monthly Average
ss. NR 106.07(3)(e)(1) and NR 106.07(4)(e)(1)	X			ATC	ATC or CTC	ATC or HH/WC	ATC		ATC or HH/WC
ss. NR 106.07(3)(e)(2) and NR 106.07(4)(e)(2)		X			CTC	CTC or HH/WC	ATC or Calculated-Procedure 2*	CTC	CTC or HH/WC
ss. NR 106.07(3)(e)(4) and NR 106.07(4)(e)(3)			X		CTC or Calculated-Procedure 1*	HH/WC	ATC or Calculated-Procedure 3 *		HH/WC
s. NR 106.07(3)(e)(3)	X		X	ATC	ATC, CTC, or Calculated-Procedure 1*	HH/WC	ATC		HH/WC
ss. NR 106.07(3)(e)(2) and NR 106.07(4)(e)(2)	X	X		ATC	CTC	ATC, CTC or HH/WC	ATC	CTC	CTC or HH/WC
s. NR 106.07(3)(e)	X	X	X	ATC	CTC	HH/WC	ATC	CTC	HH/WC
ss. NR 106.07(3)(e) and NR 106.07(4)(e)(2)		X	X		CTC	HH/WC	ATC or Calculated-Procedure 2	CTC	HH/WC
General Rule of Thumb: If you need to create a long-term limit from a short-term limit, set the long-term limit equal to the short-term limit. If you have a long-term limit, and need a short-term limit, back calculate using the applicable procedure.									
Basis of Calculated Procedures:									
	Calculated Procedure 1-				Table 5-2 of TSD (Table 8 of this guidance)				
	Calculated Procedure 2-				Table 5-1 of TSD (Table 9 of this guidance)				
	Calculated Procedure 3-				Table 5-2 of TSD (Table 8 of this guidance)				

Table 10: Expression of limits requirements for different scenarios

Chapter 9 – Antidegradation and Antibacksliding

Antidegradation and antibacksliding policies limit the impact of new or increased loads of pollution to waters of the state and prevent a lowering of water quality in surface waters unless it is demonstrated that the lowering of water quality is necessary for economic, social, environmental, or public health reasons. This chapter provides guidance on implementing these procedures as they apply to water quality based effluent limits. The antidegradation standard is established in s. NR 102.05, Wis. Adm. Code.

Antidegradation must be evaluated when there is a proposed new or increased discharge, according to s. NR 207.01(2), Wis. Adm. Code. Antibacksliding must be evaluated when a permittee requests that a limit be relaxed or removed from the permit, according to s. NR 207.10(2), Wis. Adm. Code.

To clarify, the following scenarios are not subject to antidegradation and antibacksliding:

- Changing a limit before it is in effect in a WPDES permit (through a modification or at permit reissuance)
- Some cases of changing limit expression (For example, switching from a 12-month average limit to an equivalently restrictive monthly average limit.)
- Changing variance target values in permit compliance schedules (not including effective interim limits; these are subject to antidegradation and antibacksliding)

Section 9.1: Antidegradation

The antidegradation policy is summarized in s. NR 102.05(1), Wis. Adm. Code, as follows:

> *"No waters of the state shall be lowered in quality unless it has been affirmatively demonstrated to the department that such a change is justified as a result of necessary economic and social development, provided that no new or increased effluent interferes with or becomes injurious to any assigned uses made of or presently possible in such waters."*

Consistent with Federal regulations (40 CFR § 131.12), the department antidegradation policies ensure that existing instream water uses and the level of water quality necessary to maintain these uses be protected. Where the quality exceeds the level required to meet standards, existing high-quality waters will be maintained at current levels unless an antidegradation review demonstrates that lowered water quality is needed and acceptable for social and/or economic reasons.

New or Increased Discharge:
Antidegradation reviews are needed when there is a new or increased discharge according to s. NR 207.01(2), Wis. Adm. Code.

New Discharge: defined in s. NR 207.02(8), Wis. Adm. Code, as "any point source which has not received a WPDES permit from the department prior to March 1, 1989".

Increased Discharge: defined in s. NR 207.02(6), Wis. Adm. Code. Table 11 presents a visual summary of the definition; for additional details see the full code reference.

For all discharges	
Is an increased discharge	*Not an increased discharge*
"Increased discharge" means any change in concentration, level or loading of a substance which would exceed an effluent limitation specified in a current WPDES permit…	
	…EXCLUDING initial imposition of effluent limitations for substances previously in the discharge…
…UNLESS that initial imposition is due to a changed discharge location…	
	…EXCEPT for a discharge location change needed to accommodate a mixing zone study
For discharges of BCCs to the Great Lakes:	
"Increased discharge" means any change in concentration, level or loading of a substance which would exceed an effluent limitation specified in a current WPDES permit	
OR an initial imposition of a limit due to an actual or expected increase in loading	
OR an actual or expected increase in loading due to facility changes (even if there is no change in the limit)	
	…NOT INCLUDING any increased due to normal operational variability, changes in intake pollutants or increasing the rate or hours of production within the existing production capacity

TABLE 11: DEFINITION OF AN INCREASED DISCHARGE FROM CH NR 207, WIS. ADM. CODE

Surface Water Classifications for Antidegradation:

The antidegradation process will function differently depending on the aquatic life use classification of the receiving water and whether the receiving water is classified as an ERW or ORW. The following flow diagram summarizes the process for determining the antidegradation requirements that apply based on the aquatic life use and discharge situation.

Abbreviations used in Figure 5:

N/I discharge: New or Increased Discharge as defined in ss. NR 207.02 (8) and (6) respectively.

LOWQ: Lowering of Water Quality

SLOWQ: Significant Lowering of Water Quality as defined in s. NR 207.02(11) and determined by 207.05(4)
AC: Assimilative Capacity as defined in s. NR 207.02(1)
IESD: Important Economic and Social Development as in 207.04(1)(c)

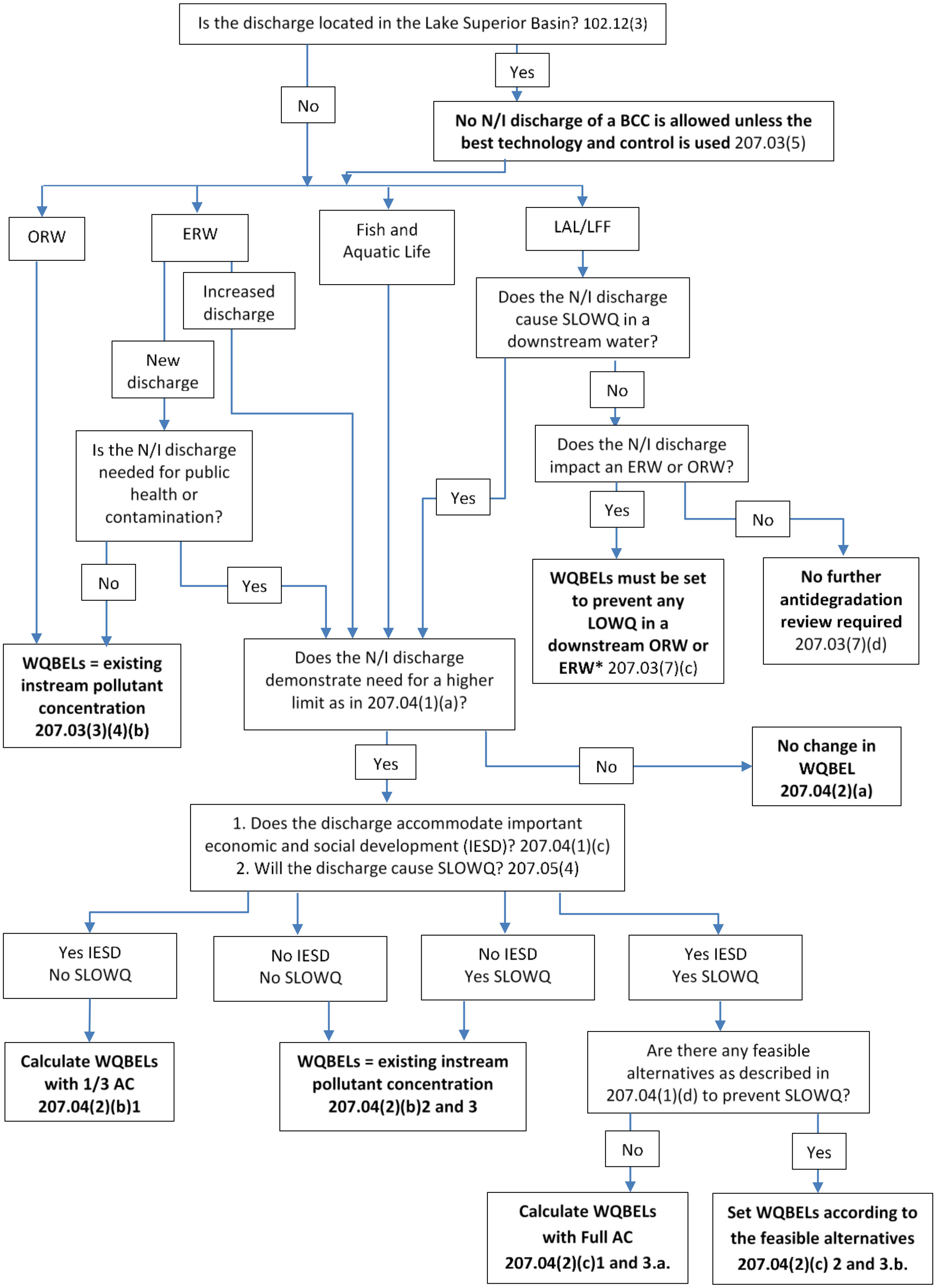


FIGURE 5: ANTIDEGRADATION REQUIREMENTS FOR WQBELS FLOW CHART

* One exception to this is that an N/I discharge may cause LOWQ in an ERW if the N/I discharge is needed for a public health or contamination issue. In this scenario, follow the procedures in ss. NR 207.04 and 207.05.

LAL and LFF Waters

Sections NR 207.03(7)(b) and (c), Wis. Adm. Code, on limited aquatic life and limited forage fish waters requires an antidegradation and antibacksliding review for a few scenarios:

- The discharge causes significant lowering of water quality in a downstream fish and aquatic life water or Great Lakes system water.
- The discharge causes lowering of water quality in a downstream outstanding resource water
- The discharge causes lowering of water quality in a downstream exceptional resource water

For other situations, contact the WQBEL Coordinator (Diane Figiel).

Bioaccumulative Compounds of Concern in the Great Lakes System

Two special provisions in ch. NR 207, Wis. Adm. Code, apply when evaluating antidegradation for a bioaccumulative compound of concern in the Great Lakes Basin:

- Any new or increased discharge of a BCC can only be allowed in the Lake Superior Basin if it is necessary after utilizing best technology in process or control using commercially available techniques with demonstrated performance levels for similar applications (s. NR 207.03(5), Wis. Adm. Code).
- Any new or increased loading of a BCC in the Great Lakes Basin is automatically considered SLOWQ. This means that an alternatives analysis as described in s. NR 207.04(1)(d), Wis. Adm. Code, would be required.

Assimilative Capacity

The assimilative capacity of a substance represents the difference between the existing level of that substance in the receiving water and the applicable water quality standard.

If the WQBEL calculator determines that there will be a new or increased discharge, an antidegradation review will be needed. The WQBEL memo should include limits based on the full available assimilative capacity and one third of the available assimilative capacity (SLOWQ and non-SLOWQ limits). Then the procedures in s. NR 207.04, Wis. Adm. Code, can be used to determine which set of limits are needed. A permittee can receive limits based on one third of the assimilative capacity if they do not provide an alternatives analysis as described in s. NR 207.04(1)(d), Wis. Adm. Code. The alternatives analysis which demonstrates that there are no pollution control measures or treatment alternatives that can prevent SLOWQ is required in order to receive limits based on the full assimilative capacity (SLOWQ limits).

Significant Lowering of Water Quality

In accordance with s. NR 207.05(4), Wis. Adm. Code, a new or increased discharge constitutes significant lowering of water quality if any of the following are true:

- The discharge of the pollutant will use more than one third of the assimilative capacity.
- For dissolved oxygen, the discharge level will be greater than:

$$\frac{2}{3} \times existing\ level + \frac{1}{3} \times water\ quality\ criteria$$

- There is any increase in mass discharge of a BCC in the Great Lakes Basin.

Section 9.2: Antibacksliding

Subchapter II of NR 207, Wis. Adm. Code, includes antibacksliding requirements which must be evaluated in order to relax or remove a limit from the permit. These requirements for WQBELs are found in s. NR 207.12(3), Wis. Adm. Code. Increased discharges must meet both antidegradation and antibacksliding requirements.

Section NR 207.12(3)(a), Wis. Adm. Code, includes specific requirements for relaxing or removing a WQBEL based on whether the water is impaired or not. However, these requirements would rarely need to be reviewed because of the exceptions in s. NR 207.12(3)(b), Wis. Adm. Code.

In almost all cases when considering increasing or removing a WQBEL, this change is only possible because some new information is available. Therefore, the exception described in s. NR 207.12(3)(b)2, Wis. Adm. Code, would typically apply:

> *New information is available that was not available at the time of permit issuance and that would have justified the application of a less stringent effluent limitation at the time of permit issuance. New information under this subdivision includes the establishment of an EPA approved total maximum daily load for the pollutant and receiving water. New information under this subdivision does not include revised regulations, guidance, or test methods. The relaxation of a water quality based effluent limitation under this subdivision that is based upon a revised wasteload allocation, a revised TMDL, or any alternative grounds for translating water quality standards into effluent limitations, is permissible only if the cumulative effect of the revised allocation results in a decrease in the amount of pollutants discharged into the receiving waters, and such revised allocations are not the result of a discharger completely or substantially eliminating its discharge of pollutants.*

The corresponding federal antibacksliding policy includes the same exception in CWA 402(o)(2). The following flow diagram from the EPA NPDES Permit Writers' Manual shows possible antibacksliding processes with the most common route for Wisconsin WQBELs highlighted.

In addition to anti-backsliding requirements that must be met to remove an effective limit from the permit, s. NR 205.067(5)(a), Wis. Adm. Code states that limits must be retained in the permit if:

- Treatment or pollutant control measures were added to comply with the water quality based effluent limitation for the pollutant and the water quality based effluent limitation took effect in a prior permit and
- The facility has the ability to alter or suspend the treatment or pollutant control measures for the pollutant to the degree that there is continued reasonable potential to exceed the applicable standard.

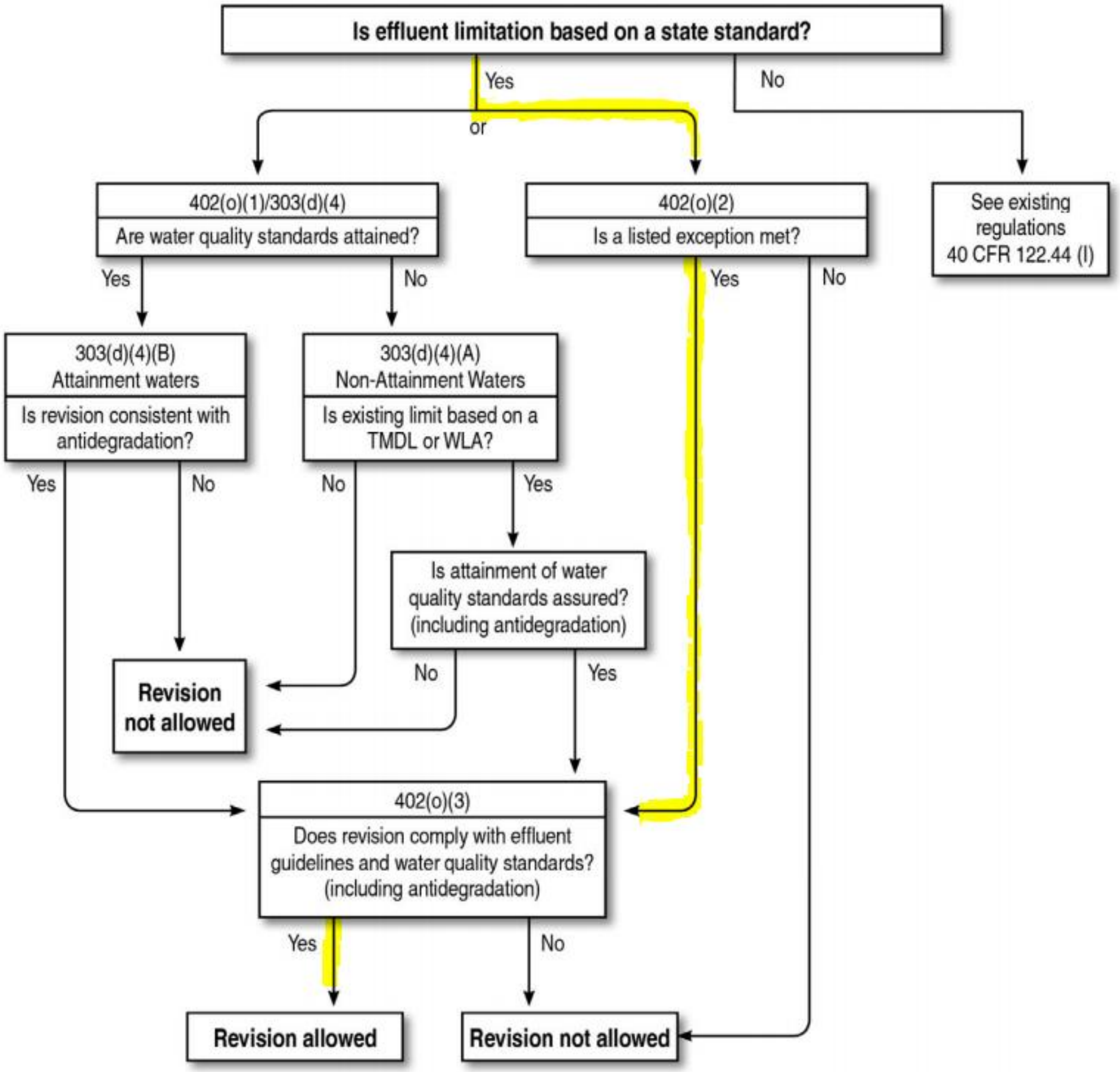


FIGURE 6: APPLICATION OF ANTI-BACKSLIDING REQUIREMENTS EXHIBIT 7-2 FROM THE NPDES PERMIT WRITERS' MANUAL, HIGHLIGHTING ADDED

*402(o) and 303(d) references refer to portions of the Clean Water Act

Section 9.3: Other Considerations for New or Increased Discharges

Several other codes include separate definitions of new or increased discharges and requirements that apply to them. In addition to antidegradation and/or antibacksliding policies, additional requirements might apply to new or increased discharges outside of those in ch. NR 207. These other requirements should be considered independently of antidegradation and antibacksliding determinations.

- **Phosphorus** (ss. NR 217.13(8), NR 217.17(4), Wis. Adm. Code)
  - A new discharger of phosphorus cannot receive a compliance schedule. Phosphorus limits for a new discharger are effective at permit issuance.
  - A new discharger of phosphorus to a phosphorus impaired water must either:
    - (a) Be allocated part of the reserve capacity or part of the wasteload allocation in a US EPA approved TMDL;
    - (b) Demonstrate the new discharge of phosphorus will improve water quality in the phosphorus impaired segment; or
    - (c) Offset the new phosphorus load through a phosphorus trade or other means with another discharge of phosphorus to the 303 (d) listed water.
  - "New discharger" means a point source which was not authorized by a WPDES permit as of **December 1, 2010**. A new discharger includes a relocation of an outfall to a different receiving water. (s. NR 217.11(3), Wis. Adm. Code)

- **Bioaccumulative compounds of concern** (ss. NR 106.06(2)(am) and (bg), Wis. Adm. Code)
  No mixing zones are allowed for BCCs from new or expanded discharges.
  - "New discharge" means any discharge from a point source that first received WPDES permit coverage from the department after **November 6, 2000**. "New discharge" does not include a discharge from a publicly owned treatment works if the discharge from the treatment works is caused by a project that is correcting or preventing a public health problem.
  - "Expanded portion of an existing discharge" means any increase in concentration, level, or loading of a BCC, which would exceed a current limit or trigger a new limit. "Expanded portion of an existing discharge" does not include an expanded discharge from a publicly owned treatment works if the expanded discharge from the treatment works is caused by a project that is correcting or preventing a public health problem.

- **Mercury** (s. NR 106.145(4)(b), Wis. Adm. Code)
  A new discharge to the Great Lakes system cannot receive an alternative mercury effluent limitation unless the proposed discharge is necessary to alleviate an imminent and substantial danger to the public health or welfare.
  - "New discharger" means any building, structure, facility or installation from which there is or may be a discharge of pollutants, as defined in s. NR 200.02 (4), Wis. Adm. Code, the construction of which commenced after **November 1, 2002**.

- **Chloride** (s. NR 106.93, Wis. Adm. Code)
  No chloride variance is allowed for new discharges.
  - A new discharge is any point source which has not been authorized under a WPDES permit prior to **February 1, 2000**. Relocation of an existing discharge may not be considered a new discharge.

- **Compliance Schedules** (ss. NR 106.117(1), Wis. Adm. Code)
  A compliance schedule for a new source, new discharger, or recommencing discharge can only be allowed for newly promulgated limits.
  - "New source" means any building, structure, facility, or installation from which there is or may be a "discharge of pollutants," the construction of which commenced:
    - After promulgation of standards of performance under section 306 of CWA which are applicable to such source, or
    - After proposal of standards of performance in accordance with section 306 of CWA which are applicable to such source, but only if the standards are promulgated in accordance with section 306 within 120 days of their proposal.
  - "New discharger" means any building, structure, facility, or installation from which there is or may be a "discharge of pollutants:
    - That did not commence the "discharge of pollutants" at a particular "site" prior to **August 13, 1979**;
    - Which is not a "new source" and
    - Which has never received a NPDES permit for discharges at that "site."
  - "Recommencing discharger" means a permitted source that recommences discharge after terminating its operations.

Because of the complexity of these separate determinations and requirements that might apply to a new or increased discharge, care should be taken to not confuse one code's definitions and requirements with another. Simply referring to a discharge as a "new discharge" is not enough detail because a "NR 207-new discharge" might not also be a "NR 217-new discharge". When one or more of the above requirements apply to a discharge, the WQBEL memo should provide clear code references with the determinations.

References

Benefield, L.D., Judkins, J.F. and Weand, B.L., 1982. *Process chemistry for water and wastewater treatment*. Prentice Hall.

Gebert, W.A., Garn, H.S. and Rose, W.J., 2016. *Changes in streamflow characteristics in Wisconsin as related to precipitation and land use* (No. 2015-5140). US Geological Survey.

Gebert, W.A., 1981. *Low-flow characteristics of streams in the Central Wisconsin River basin, Wisconsin* (No. 81-495). US Geological Survey.

Gebert, W.A., 1979. *Low-flow characteristics of streams in the Lake Superior Basin, Wisconsin* (No. 79-38). US Geological Survey.

Gebert, W.A., 1978. *Low-flow characteristics of streams in the Lower Wisconsin River basin* (Vol. 77). Department of the Interior, Geological Survey, Water Resources Division.

Gebert, W.A., 1979. *Low-Flow Characteristics of Streams in the Red Cedar River Basin* (No. 79-29). US Geological Survey.

Gebert, W.A., 1980. *Low-flow characteristics of streams in the Upper Wisconsin River basin, Wisconsin* (No. 80-691). US Geological Survey.

Gebert, W. A., 1971, Low-flow frequency of Wisconsin streams: U.S. Geological Survey Hydrologic Investigations Atlas HA-390.

Holmstrom, B.K., 1982. *Low-flow Characteristics of Streams in the Lake Michigan Basin, Wisconsin* (Vol. 81, No. 1193). US Geological Survey.

Holmstrom, B.K., 1980. *Low-flow characteristics of streams in the Menominee-Oconto-Peshtigo River basin, Wisconsin* (Vol. 80, No. 749). US Department of the Interior, Geological Survey.

Holmstrom, B.K., 1978. *Low-flow characteristics of streams in the Rock-Fox River basin, Wisconsin* (No. 78-85). US Geological Survey.

Holmstrom, B.K., 1980. *Low-flow characteristics of streams in the St. Croix River basin, Wisconsin* (No. 80-696). US Geological Survey.

Holmstrom, B.K., 1979. *Low-flow characteristics of streams in the Trempealeau-Black River basin, Wisconsin* (No. 79-9). US Geological Survey.

Kiang, J.E., K.M. Flynn, T. Zhai, P. Hummel, and G. Granato. 2018. SWToolbox: A Surface-Water Tool-Box for Statistical Analysis of Streamflow Time Series: Techniques and Methods 4–A11. U.S. Geological Survey, 33 pp. https://doi.org/10.3133/tm4A11.

Lyons, John, and Diebel, M. W. 2019. *Wisconsin Stream Natural Community Model,* Version 2.1. Wisconsin Dept. of Natural Resources. Madison, Wisconsin. http://dnr.wi.gov/topic/surfacewater/wcv/.

Menuz, D.R., A.S. Ruesch, and M.W. Diebel. 2013. 1:24K Wisconsin Hydrography Dataset Plus (WHDPlus) Attribution Metadata. Wisconsin Department of Natural Resources, Bureau of Water Quality. Madison, WI.

Ries, K.G., III, J.K. Newson, M.J. Smith, J.D. Guthrie, P.A. Steeves, T.L. Haluska, K.R. Kolb, R.F. Thompson, R.D. Santoro, and H.W. Vraga. 2017. StreamStats, Version 4. U.S. Geological Survey, Fact Sheet 2017–3046, 4 pp. https://doi.org/10.3133/fs20173046.

Riggs, H.C., 1972, Low-flow investigations: Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 4, Chapter B1, 18 p.

Ruesch, A.S., D.R. Menuz, and M.W. Diebel. 2013. 1:24K Wisconsin Hydrography Dataset (WHD) Creation Toolset. Wisconsin Department of Natural Resources, Bureau of Water Quality. Madison, WI.

Stedfast, D.A., 1979. *Low-flow characteristics of streams in the Pecatonica-Sugar River Basin, Wisconsin* (No. 79-1274-Pecatonica River, Sugar River). US Geological Survey.

US EPA Office of Water, 2018. *Low Flow Statistics Tools - A How-To Handbook for NPDES Permit Writers.* EPA-833-B-18-001

United States. Environmental Protection Agency. Office of Water Regulations, 1985. Technical support document for water quality-based toxics control. Office of Water Enforcement and Permits, Office of Water Regulations and Standards, US Environmental Protection Agency.

Appendices:

Appendix A: Low Flow Calculation Methods

There are three methods that may be used to calculate receiving water low flows for use in WQBEL evaluations: (1) direct calculation using empirical data from continuous gauge sites, (2) regression analysis using base flow measurements, and (3) multiple regression analysis for ungauged or minimally gauged sites. The methods described below are ordered from most accurate to least accurate. Details about each listed resource are provided at the end of this section.

(1) Direct calculation using empirical data from continuous gauge sites:
At sites where continuous gauge data is available, 7-Q_{10}, 7-Q_2 and other low flow frequency values can be directly calculated. This is typically done using the Log Pearson III method. The USGS Low-Flow Characteristics Reports used this method along with a Riggs 1972 plotting position analysis. In accordance with s. NR 217.13(2)(b), Wis. Adm. Code, at least 10 years of data should be used to calculate low flow estimates for phosphorus limits.

When a long-term record of continuous flow data is available, it may be appropriate to only use more recent flow data to calculate low flows. In a recent report, USGS evaluated streamflow trends in long-term records since 1915 and found that low flows have generally increased over time in agricultural watersheds (Gerbert et. al. 2016). The report recommended flow records starting in 1969 for use in future low flow studies. This date may generally be used as a cutoff for selecting flow data when a long-term continuous flow record is available that extends before this date. Care should be taken to make sure that the selected date range reflects recent climate conditions, and recent flows are not so high that the receiving water would not be protected if future years experience drier periods.

Low-flows calculated using this method are found in:

- USGS Streamflow Gauge Low-Flow Stats layer in WPDES viewer
- USGS Low-Flow Characteristics Reports: Category A
- StreamStats from USGS
- SWToolbox from USGS

(2) Regression analysis using base flow measurements:
Some sites don’t have continuous flow data, but they do have a few base flow measurements. Base flow measurements are taken during a dry part of the year when stream flows are expected to be lowest. Since different streams will behave differently in dry and wet parts of the year, the lowest flow measurements possible should be used to estimate 7-Q_{10} and 7-Q_2 values. The low flows are estimated by “a relation line established by correlating… base-flow discharge measurements at these stations with the concurrent discharge at continuous-record gaging stations in the area” (Gebert 1971). An example of this method is shown in Figure 7.

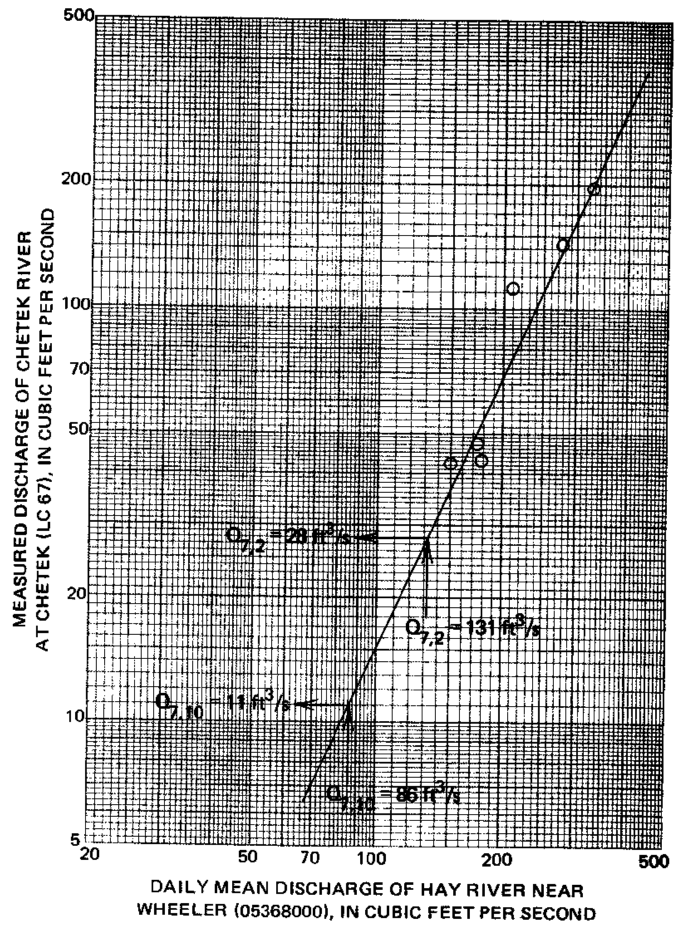


FIGURE 7: "METHOD OF ESTIMATING Q7,2 AND Q7,10 AT PROJECT STATIONS." (HOLMSTROM 1979)

Different methods may be employed to fit a regression line depending on the situation. The accuracy of this method depends heavily on the quantity and quality of base flow measurements for the site. Because the only field data needed for this method are a few base flow measurements, a permittee could collect the data required for this method. Methods and data sheets for measuring base flow can be found in the resources on the Water Action Volunteers website. If a permittee is interested in collecting this data to obtain updated flow estimates, they should contact their regional WQBEL calculator. The WQBEL calculator will need to work with department modeling experts and/or USGS in order to plan appropriate base flow monitoring and perform a regression analysis with a nearby continuous gauge site.

Low-flows from this method are found in:

- USGS Low-Flow Characteristics Reports: Categories B and C
- Discharger-specific estimates provided by USGS (typically in letter format): These estimates are most often from method (2). Sometimes base flow measurements are related to multiple nearby gauge stations and sometimes no base flow measurements are available and USGS generals a base flow estimate for them.

- Can be calculated by USGS or a department modeling expert using facility-collected base flow estimates

(3) Multiple regression analysis for ungauged or minimally gauged sites:
USGS has developed equations for estimating low flows in Wisconsin where no or minimal streamflow data exists. Estimates using method (2) are only reasonably accurate when at least three base flow measurements are used. However, a multiple regression equation can be used to estimate low flows at sites with less than three base flow measurements.

It is known that low flows are dependent on climate, topography, and geology of the drainage area. USGS has performed a multiple regression analysis for most of the basins in Wisconsin using the following basin characteristics: drainage area, main channel slope, main-channel length, basin storage, forest cover, mean annual precipitation, soil-infiltration rate, mean annual snowfall, a base-flow index, hydraulic conductivity, transmissivity, and drainage density.

The analysis resulted in basin-specific equation to estimate low flows that can be found in the USGS Low-Flow Characteristics Reports. Several types of equations were developed with dependence on different combinations of the basin characteristics, but the equations with the lowest standard error overall were based only on drainage area and base-flow. USGS developed these equations for all major drainage basins except the Chippewa River and Fox-Wolf River basins. In 2018, department staff used the same methods as USGS to create multiple-regression equations for these last two basins as well. The equations are as follows using the coefficients listed in Table 12. The Central Wisconsin and Trempealeau-Black basins were divided into sub-basins with separate equations. Maps at the end of this appendix show the division of those basins.

$$7Q_2 = C2 \times DA^{A2} \times \left(\frac{baseflow}{DA}\right)^{B2}$$

$$7Q_{10} = C10 \times DA^{A10} \times \left(\frac{baseflow}{DA}\right)^{B10}$$

Where:

DA = Drainage area in square miles

Base flow: The 90% exceedance flow rate in cfs

A2, B2, C2, A10, B10, and C10 are drainage basin-specific coefficients provided in Table 3

Basin	Report	C2	A2	B2	Standard error (7Q2)	C10	A10	B10	Standard error (7Q10)
Lower Wisconsin[1]	USGS 77-118	0.571	1.07	0.87	28%	0.463	1.07	0.948	38%
Rock-Fox	USGS 78-85	0.747	1.09	1.12	55%	0.554	1.15	1.39	62%
Pecatonica-Sugar	USGS 79-1274	0.754	0.96	0.792	39%	0.611	0.962	0.999	51%
Red Cedar	USGS 79-29	0.812	1.06	1.14	25%	0.425	1.12	1.26	34%
Lake Superior[1]	USGS 79-38	0.664	1.02	0.985	45%	0.321	1.19	1.28	84%
Trempealeau-Black									
Glaciated	USGS 79-9	0.539	1.07	0.997	16%	0.434	1.04	1.23	22%
Driftless[1]	USGS 79-9	0.655	1.02	0.694	45%	0.452	1.08	0.817	76%
Upper Wisconsin[1]	USGS 80-691	0.808	0.917	0.827	46%	0.541	0.986	1	56%
St. Croix	USGS 80-696	0.492	1.14	1.01	38%	0.235	1.28	1.21	52%
Menominee-Oconto-Peshtigo	USGS 80-749	0.886	1.04	1.25	32%	0.627	1.08	1.45	49%
Lake Michigan	USGS 81-1193	0.78	1.08	1.15	42%	0.262	1.22	1.3	69%
Central Wisconsin									
Central Sand Plain	USGS 81-495	1.01	0.922	0.662	10%	0.7	0.985	0.9	24%
Westside	USGS 81-495	2.18	0.893	1.24	40%	1.12	0.815	1.23	61%
Northeast area	USGS 81-495	0.808	0.917	0.827	36%	0.541	0.986	1	56%
Southwest area	USGS 81-495	0.571	1.07	0.87	28%	0.463	1.07	0.948	38%
Chippewa Basin	WDNR 2018	0.706	1.046	1.1		0.401	1.102	1.297	
Fox-Wolf Basin	WDNR 2018	1.534	0.956	1.41		0.969	1.022	1.849	

TABLE 12: REGRESSION COEFFICIENTS FOR EQUATIONS FROM THE USGS LOW-FLOW CHARACTERISTICS REPORTS

[1.] The report includes other equations with a lower standard error that are based on different basin characteristics.

The base flow index which these reports reference is the base flow divided by the drainage area. For sites with no base flow measurements, USGS has created maps with estimated base flow indices, but site-specific drainage area and estimated base flow information is preferable in most cases. Each base-flow index on these maps is based on a single base-flow measurement, so there is usually a more recent and accurate estimate available. USGS defines base flow as the 90% exceedance flow. Base flow estimates and drainage area can be obtained from the Wisconsin Stream Model and WHDPlus (information in SWDV in the "Natural Community Model" layer).

Comparison of flows calculated with the multiple regression equations and site-specific low flows provided my USGS has shown that these equations generally over-estimate low flows. Due to the high standard error in these equations, staff should avoid using method (3) for WQBEL calculation purposes. These equations are mostly used for calculating limits for protection of downstream waters where a USGS low flow estimate does not already exist.

Since these equations are based largely on expected runoff and drainage area, they may be less accurate in larger drainage areas. In each of the reports, USGS states that the multiple regression equations should not be used in streams with a drainage area over 150 mi^2. Some of the basin reports include other equations based on different basin characteristics (transmissivity, forest cover, etc.) which have a lower standard error. The inputs required for these equations are not usually available, but when the needed information is available, these equations may provide more accurate estimates.

Low-flows from this method are found in:

- Some flows in the USGS Low-Flow Characteristics Reports (uses a single base flow measurement to calculate a base flow index)
- The “Stream Natural Community” layer in SWDV or the “Min. Seven Day Streamflow (cfs)” layer in the internal WPDES viewer (uses a modeled base flow from WHD-Plus)

Selecting a flow estimate source:
Several factors should be considered when selecting the low flow estimation method to use. If additional data is required to update low flow estimates, consider which limits, if any, are affected by a different low flow estimate. Weigh the importance of recent data versus distance from the site in question versus accuracy of the estimation method. Generally, the relative impact of these factors on the accuracy of the estimate could be ranked: method > distance > time.

Referenced Stream Flow Resources:

- WPDES Viewer
- Surface Water Data Viewer (SWDV)
  - Surface Water Data Viewer User Guide
  - Data Layer Inventory
- StreamStats from USGS
- SWToolbox from USGS
- USGS Low-Flow Characteristics Reports:
  Basin Specific Reports that contain flows determined from methods (1), (2), and (3) as well as basin-wide equations to estimate flows for ungauged sites (method (3)). A “Basis of estimate” is given for each site which corresponds to either method (1), (2) or (3). Reports are not available for the Chippewa and Upper Fox-Wolf basins.
  - Low-Flow Characteristics of Streams in the Central Wisconsin River Basin
  - Low-Flow Characteristics of Streams in the Lake Michigan Basin
  - Low-Flow Characteristics of Streams in the Lower Wisconsin River Basin
  - Low-Flow Characteristics of Streams in the Menominee-Oconto-Peshtigo River Basin
  - Low-Flow Characteristics of Streams in the Pecatonica-Sugar River Basin
  - Low-Flow Characteristics of Streams in the Red Cedar River Basin
  - Low-Flow Characteristics of Streams in the Rock-Fox River Basin, Wisconsin
  - Low-Flow Characteristics of Streams in the St. Croix River Basin

- Low-Flow Characteristics of Streams in the Lake Superior Basin
- Low-Flow Characteristics of Streams in the Trempealeau-Black River Basin
- Low-Flow Characteristics of Streams in the Upper Wisconsin River Basin

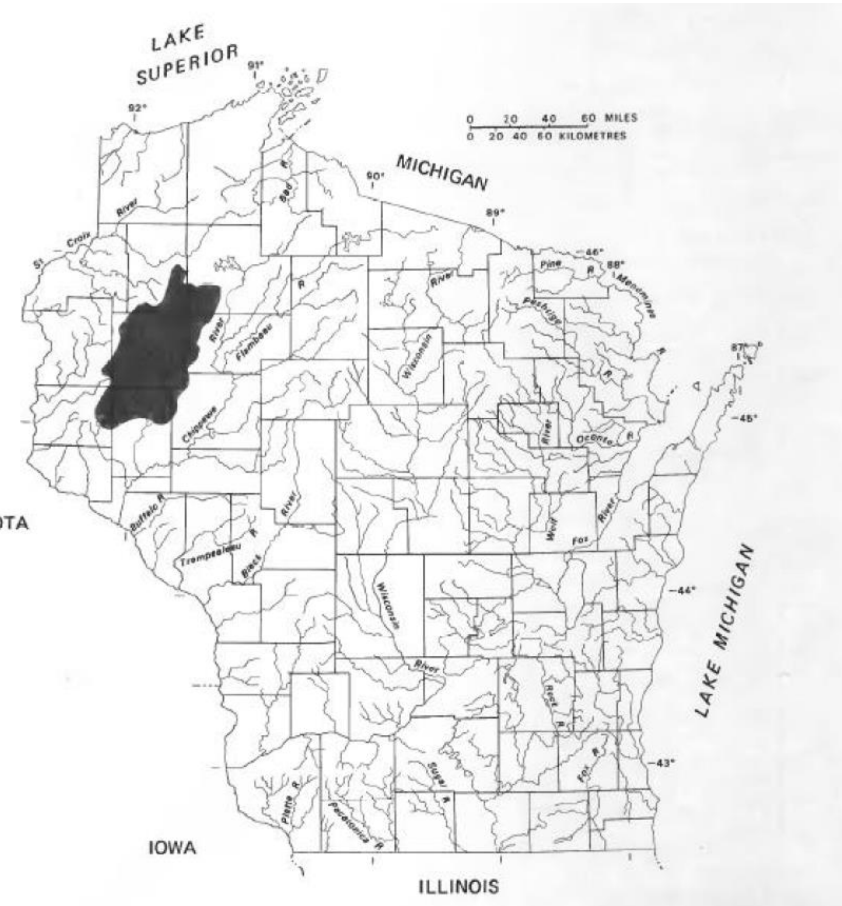
- EPA-USGS Webcast from February 8, 2018 - *Using the Surface Water Toolbox for Estimating Critical Low Flow Statistics*
- Low Flow Statistics Tools: A How-To Handbook for NPDES Permit Writers (October 2018) from EPA

Basin Maps for USGS Low Flow Characteristics Reports

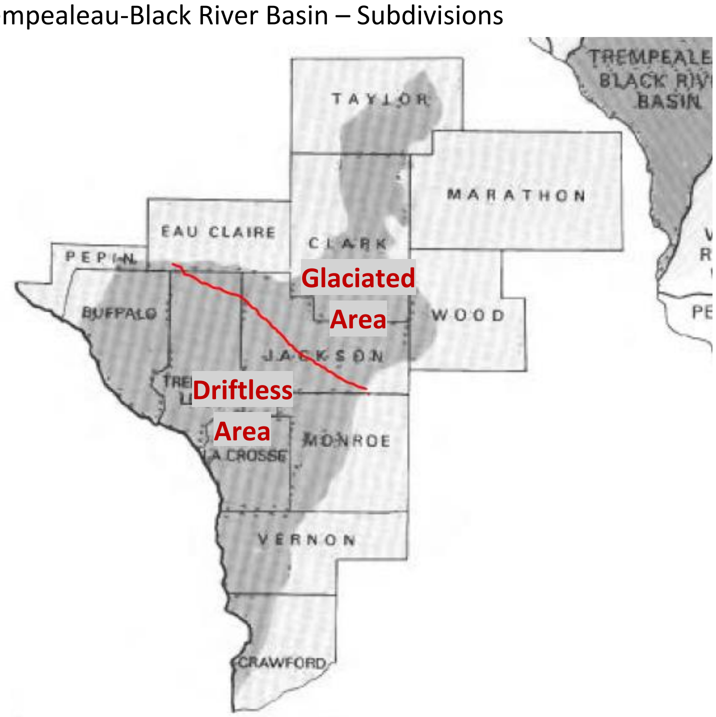
The following maps show the areas covered by each of the USGS Low Flow Characteristic Reports referenced in Section 3.1 and by Table 3.

General Basins Map

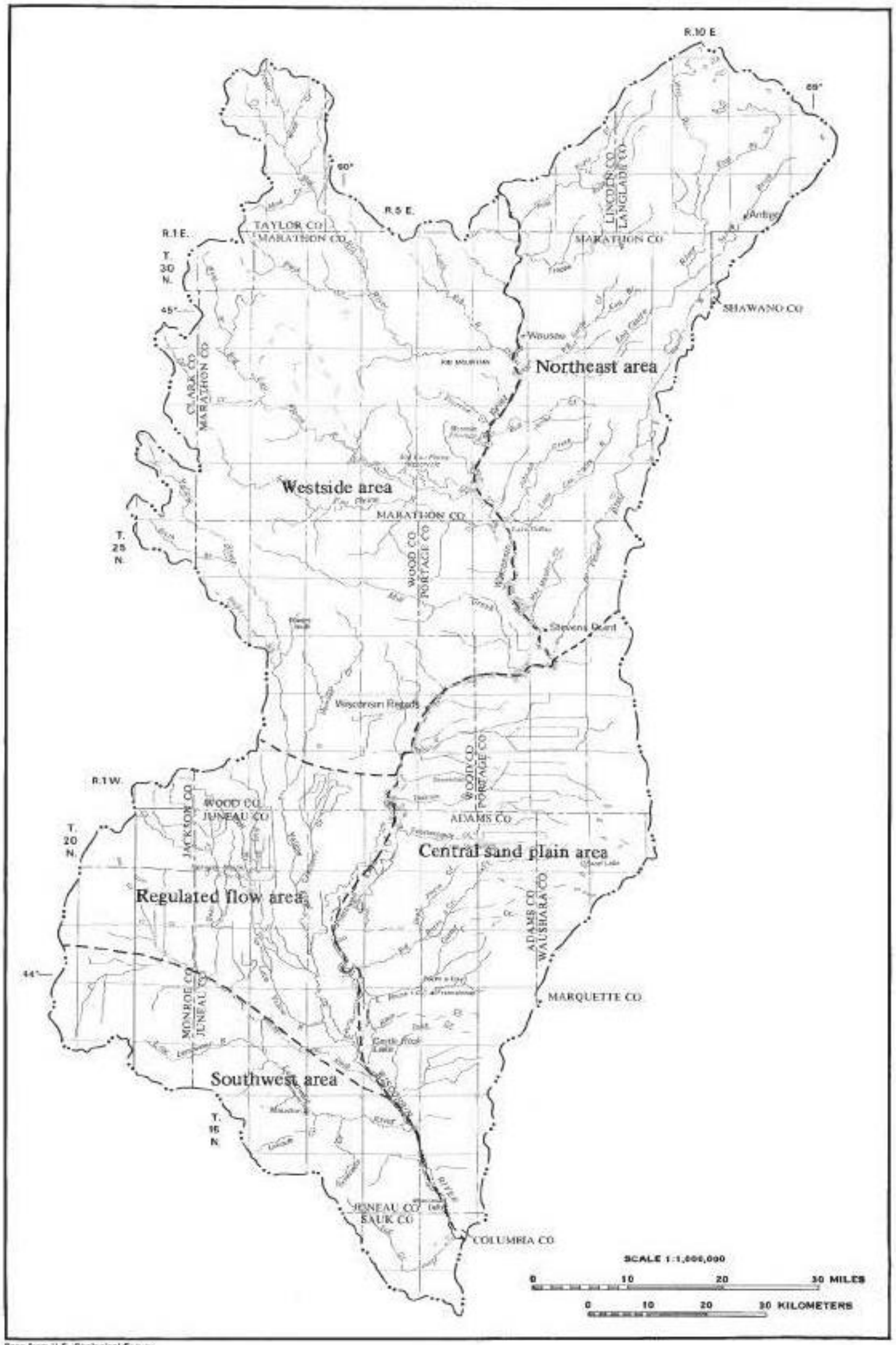
Red Cedar River Basin Location



Trempealeau-Black River Basin – Subdivisions



Central Wisconsin River Basin - Subdivisions



Base from U.S. Geological Survey State base map, 1968

Appendix B: Methods for Evaluating Appropriateness of Mix Hardness

Under most conditions in natural waters in Wisconsin, hardness can be considered a conservative parameter. But in some situations, the water chemistry may cause hardness dissolution or hardness precipitation.

To summarize, using mix hardness makes sense (significantly impacts the calculation) where effluent hardness is significantly higher than receiving water hardness and the effluent flow rate makes up a significant portion of the mixed flow. Mix hardness is a protective assumption when the receiving water hardness and pH are relatively low, as this rules out hardness precipitation. This scenario most often occurs in the northern part of the state and sometimes in the western part of the state.

To determine if hardness may precipitate out, the saturation pH must be calculated and compared to the receiving water pH. Equations and methods to estimate saturation pH are provided in *Process Chemistry for Water and Wastewater Treatment* (Benefield, Judkins, and Weand). These calculations require effluent and receiving water alkalinity, total dissolved solids, pH, and hardness data.

If the data needed for this model is not available, the permittee may instead take hardness measurements in-stream at a few points where the effluent is mixing and completely mixed with the receiving water. Rather than using a model to determine whether or not precipitation occurs, the measured mix hardness may be substituted for receiving water hardness for calculation of chronic limits.

Dissolution

If dissolution of calcium or magnesium would occur, hardness levels would rise. This should not cause a water quality concern in most cases because metals are less toxic in harder waters. This situation is unlikely because there is little carbonate rock from which to dissolve calcium or magnesium ions in the parts of the state where the mix hardness calculation is most often applied. If it is believed that significant dissolution is occurring just after discharge, and limits are overly conservative, a more appropriate hardness value could be obtained through instream monitoring just downstream of where the mixing and dissolution is believed to occur.

Precipitation

If hardness levels added to the receiving water are sufficiently high, precipitation of minerals occurs, causing the mix hardness to drop below the level that would be calculated using a simple mass balance. This would occur when the mix hardness value is greater than the "hardness capacity" of the water, which is dependent on several water chemistry factors. Before applying a mix-hardness value for limit calculation, the possibility of hardness precipitation should be ruled out to ensure that the calculated limit will be sufficiently protective of water quality.

One method used in the water supply industry to determine whether a given water is above or below the calcium carbonate saturation point is to calculate what is called the Langelier Index.

$$LI = pH - pH_s$$

Where:

LI = Langelier Index

pH = the receiving water pH

pH_s = the saturation pH of the mix receiving water

If the receiving water pH is greater than the saturation pH (LI > 0), the water is over-saturated and calcium carbonate will precipitate. If the Langelier index is positive, a simple mass-balance mix hardness calculation would not be protective of water quality.

Following the procedure given in *Process Chemistry for Water and Wastewater Treatment* by Benefield, Judkins, and Weand, saturation pH may be calculated using the following equation which is applicable over a pH range of 6.5 to 9.5:

$$pH_s = pK_2' + pCa^{2+} - pK_s' - \log(2 \times [Alk]) - \log(\gamma_m)$$

Calculating the inputs for this equation involves several effluent and water quality parameters, not all of which may be available at the site. Table 13 presents the saturation pH at 25°C calculated over a range of scenarios that roughly cover what would be expected in a real discharge situation. The saturation pH is shown with a color scale with lower values (more likely to precipitate) in red and higher values (less likely to precipitate) in green.

IWC[1]	Effluent Hardness (mg/L $CaCO_3$)	Receiving Water Hardness (mg/L $CaCO_3$)	Effluent Chloride (mg/L)	Receiving TDS (mg/L)	Mix Alkalinity[2] (mg/L)	**Saturation pH[3]**
10%	300	50	100	150	71	7.53
40%	300	50	100	150	143	7.26
80%	300	50	100	150	238	7.08
60%	100	50	100	150	76	8.00
60%	200	50	100	150	133	7.47
60%	300	50	100	150	190	7.16
60%	400	50	100	150	247	6.93
60%	300	20	100	150	179	7.18
60%	300	80	100	150	201	7.13
60%	300	150	100	150	228	7.08
60%	300	250	100	150	266	7.01
60%	300	50	10	150	190	7.13
60%	300	50	150	150	190	7.17
60%	300	50	300	150	190	7.20
60%	300	50	100	50	190	7.15
60%	300	50	100	200	190	7.16
60%	300	50	100	450	190	7.19

TABLE 13: ESTIMATED HARDNESS SATURATION PH AT 25°C UNDER VARIOUS DISCHARGE AND STREAM CONDITIONS

1. IWC is calculated using the effluent flow rate and percent of the receiving water used for mixing (usually 25% for chronic metals limits)
2. In this table, alkalinity is assumed to equal 95% of the mix hardness level
3. The receiving water pH should be lower than this pH in order to demonstrate that hardness precipitation is unlikely.

Note that the parameters that have the greatest effect on the saturation pH are IWC, effluent hardness, and receiving water hardness. Effluent chloride (which is used to estimate effluent TDS) and the receiving water TDS have minimal impact on the calculation over the expected range of these parameters. The saturation pH decreases as the overall mix hardness increases simply because the higher the mix hardness value, the closer the water is to its "hardness capacity" and the closer it gets to precipitating out that hardness.

By comparing the scenarios in the table above to a specific situation, the limit calculator may make a determination that hardness precipitation is or is not likely. This determination should be documented in the WQBEL memo.

Detailed Calculation Method:
The rest of this appendix summarizes the calculations for the inputs for the saturation pH equation for calculating a site-specific hardness saturation pH.

Table 14 provides values of pK'_2, pK'_s, and γ_m at 25°C and several TDS levels. The detailed equations for these parameters are also provided below.

TDS (mg/L)	log (γ_m)	pK'_2	pK'_s
50	-0.0111	10.29	8.24
100	-0.0239	10.23	8.14
200	-0.0330	10.20	8.07
400	-0.0450	10.15	7.97
1000	-0.0659	10.07	7.80

TABLE 14: HARDNESS SATURATION PARAMETER VALUES BASED ON TOTAL DISSOLVED SOLIDS CONCENTRATION AT 25°C

γ_m: Activity Coefficient

$$\text{Ionic Strength: I} = 2.5 \times 10^{-5} \times TDS$$

$$\log(\gamma_m) = -AZ^2\left(\frac{\sqrt{I}}{1+\sqrt{I}} - 0.3 \times I\right)$$

$$A = 1.82 \times 10^6 (D \times T)^{-3/2}$$

Where:

T = temperature in K

D = dielectric constant for water = 78.3
Z = oxidation number of chemical species = 1

pK'₂

$$pK_2 = \frac{2902.39}{T} + 0.02379 \times T - 6.498$$

$$K_2 = 10^{-(pK_2)}$$

$$\log(\gamma_D) = -AZ^2\left(\frac{\sqrt{I}}{1+\sqrt{I}} - 0.3 \times I\right)$$

Z = oxidation number of chemical species = 2
I = same as calculated above
A = same as calculated above

$$K_2' = \frac{K_2}{\gamma_D}$$

$$pK_2' = \log\left(\frac{1}{K_2'}\right)$$

pK'ₛ

$$pK_s = 0.01183 \times t + 8.03$$

t = water temperature in °C

$$K_s = 10^{-(pKs)}$$

$$K_s' = \frac{K_s}{(\gamma_D)^2}$$

$$pK_s' = \log\left(\frac{1}{K_s'}\right)$$

pCa^{2+}

$$pCa^{2+} = log\left(\frac{1}{[Ca^{2+}]}\right)$$

Ca^{2+} = calcium concentration in moles/L

Since calcium data is not typically available, hardness may be substituted. Although hardness includes both calcium and magnesium ions, assuming that all hardness is calcium results in a conservative estimate. To convert from mg/L CaCO3 to mols Ca/L:

$$Estimate\ of\ Ca\ \left(\frac{mol}{L}\right) = hardness\left(\frac{mg}{L} as\ CaCO_3\right) \times \frac{1\ g}{1000\ mg} \times \frac{1\ mol}{100\ g\ CaCO_3}$$

[Alk]: Alkalinity concentration

[Alk] = mix alkalinity in moles per liter

Hardness and alkalinity are different but they're generally close approximations of each other. If alkalinity information is unavailable, hardness data may be substituted. Note that in natural waters alkalinity is typically a little less than hardness.

Total Dissolved Solids Estimate:

Effluent and receiving water TDS data is not typically available. For effluent, TDS can be roughly estimated as a sum of total hardness and sodium chloride concentrations.

$$TDS\left(\frac{mg}{L}\right) = total\ hardness\ \left(\frac{mg}{L}\right) + 1.65 \times Cl^{-}\left(\frac{mg}{L}\right)$$

Its assumed that all chloride in the effluent comes from sodium chloride. The 1.65 factor is a factor to account for the additional sodium mass that accompanies the measured chloride levels.

In the receiving water, total solids and total suspended solids data may be available. In this case, TDS may be estimated as

$$TDS\left(\frac{mg}{L}\right) = total\ solids\ \left(\frac{mg}{L}\right) - total\ suspended\ solids\left(\frac{mg}{L}\right)$$

Appendix C: Surface Water Data for Dissolved Metals Calculations

The following table contains particulate-bound concentrations (µg/g) of metals in Wisconsin streams. All data are from cooperative studies between the department and the University of Wisconsin. In most cases, the data represent single grab samples collected in 1992 or 1993. Other (unpublished) data indicate that the particulate-bound concentration does not vary to a significant extent with a hydrograph of a stream. Site locations can be determined by using the attached map.

Particulate-bound metal concentrations (ug/g)								
Site	As	Cd	Cr	Cu	Ni	Pb	Hg	Zn
Big Eau Pleine @ Cherokee							0.24	
Big Rib @ Goodrich							0.14	
Black (E. Fork)							0.088	
Black @ Hemlock							0.14	
Black @ Medford		0.60		45		40		146
Bois Brule (Lake Superior)							0.051	
Chaffee Creek @ Dakota	9.2		64		10	20	1.12	
Chippewa @ Durand		0.56		4.0		43	0.048	104
Chippewa @ Winter		0.16		3.9		41		80
Duck Creek @ Oneida	1.3		12		7.2	7.7	0.131	
Fish Creek							0.019	
Flambeau @ Park Falls		0.88		31		32		108
Fox @ Wrightstown		0.70		12		49	0.46	112
Grand (S. Fork) @ Kingston							0.053	
Kickapoo @ Oil City							0.09	
Kinnickinnic @ Chase Avenue							0.24	
Lake Superior								
Lake Michigan	93	3.7	50	59	108	49		144
Lincoln Crk. @ 47th St. Park							0.56	
Milwaukee (N. Branch) @ Batav.	2.7		22		14	13.2	0.19	
Milwaukee @ Estebrook Park		1.65		41		67	0.11	248
Mississippi @ Alma		1.86		8.2		67		165
Mississippi @ Diamond B.		1.23		16		40		137
Mississippi @ Trenton							0.17	
Moose @ Moose Lake	4.6		11		6.8	8.5	0.23	
Nemadji River							0.057	
Otter Creek @ Darlington							0.045	
Pecatonica (E. Branch) @ Hollandale							0.044	
Pensaukee (S. Branch) @ Krakow							0.21	
Pigeon Creek @ York							0.061	
Popple River	3.2		3		2.7	12	0.97	

Particulate-bound metal concentrations (ug/g)								
Site	As	Cd	Cr	Cu	Ni	Pb	Hg	Zn
Rattlesnake Crk. @ Beetown	6.1		21		18	37	0.11	
Rock @ Waupun		0.41		28		49		213
Rush @ Martell							0.14	
Sand River							0.031	
Sheboygan @ Sheboygan Marsh							0.045	
Sheboygan @ Dotyville		0.76		36		35	0.056	1280
Ten Mile Creek @ Nekoosa							0.52	
Thornapple @ Dairy Center							0.24	
Tomorrow @ Nelsonville							0.13	
Upper Eau Claire @ Gordon							0.27	
Upper Tamarack (MN)							0.29	
Wisconsin @ Biron		0.53		3.7		21		64
Wisconsin @ Conover		0.60		73		45	0.24	108
Wisconsin @ Plover							0.18	
Wolf @ Lily		0.60		0.82		22	0.17	112
Wolf @ Shiocton							0.18	

The following data represent the "total recoverable" and "dissolved" concentrations of metals in monitored surface waters. The dissolved concentration refers to the sample result for water filtered at 0.45 µm pore size. Approximate site locations identified by site number are shown on the map following this table. These data are the same as those found in the memorandum from David Webb, March 14, 1995. Most values are geometric means of two to three data points.

Surface Water Metals Data – Total Recoverable and Dissolved									
Site No.	Site Name		Al (µg/L)	Cd (µg/L)	Cr (µg/L)	Cu (µg/L)	Pb (µg/L)	Hg (ng/L)	Zn (µg/L)
1	Big Eau Pleine at Cherokee	total rec.	137.79	0.0251	0.337	1.266	0.2832	5.531	2.011
		dissolved	28.52	0.0155	0.256	1.102	0.0956	4.436	1.215
2	Big Rib R. at Goodrich	total rec.	114.39	0.0115	0.391	0.795	0.1404	4.350	1.831
		dissolved	45.32	0.0218	0.326	0.765	0.0791	3.945	1.409
2a	Black Earth Creek at Black Earth	total rec.	1153.0	0.0787	2.430	3.840	2.646	NA	12.710
		dissolved	13.20	0.0120	0.479	1.590	0.0570	NA	1.500
3	Black R. at Hemlock	total rec.	100.38	0.0090	0.622	1.265	0.1784	4.469	1.710
		dissolved	27.52	0.0098	0.239	1.181	0.0724	3.934	1.303
4	Black R. at Medford	total rec.	490.00	0.0149	NA	0.938	0.3550	4.684	1.900
		dissolved	19.30	0.0102	NA	0.588	0.0500	NA	0.775
5	Black R. (E.Fork) at Hatfield	total rec.	463.55	0.0469	0.995	1.237	0.6471	7.188	8.012
		dissolved	157.31	0.0243	0.659	0.975	0.1253	5.984	7.052
6	Black R. (MI) at mouth	total rec.	137.00	0.0198	0.679	2.098	0.2788	6.436	2.031
		dissolved	16.98	0.0138	0.544	1.866	0.1091	4.396	1.362

Surface Water Metals Data – Total Recoverable and Dissolved									
Site No.	Site Name		Al (µg/L)	Cd (µg/L)	Cr (µg/L)	Cu (µg/L)	Pb (µg/L)	Hg (ng/L)	Zn (µg/L)
7	Bois Brule at mouth (Riv. vw dr.)	total rec.	206.72	0.0111	1.173	1.039	0.2827	2.393	1.720
		dissolved	38.30	0.0075	0.522	0.492	0.0475	1.953	0.433
8	Chaffee Creek at Dakota	total rec.	36.34	0.0035	0.694	0.251	0.1451	6.879	0.966
		dissolved	8.94	0.0039	0.624	0.190	0.0473	2.388	0.473
9	Chippewa R. at Durand	total rec.	138.93	0.0103	0.500	1.210	0.3384	4.376	1.413
		dissolved	24.80	0.0082	0.384	1.099	0.1041	4.323	0.606
10	Chippewa R. at Winter	total rec.	98.60	0.0108	NA	0.753	0.3920	4.253	1.200
		dissolved	50.50	0.0101	NA	0.735	0.1980	NA	0.825
11	Duck Creek at Oneida	total rec.	85.72	0.0170	0.324	1.992	0.1391	2.757	1.806
		dissolved	8.30	0.0152	0.267	1.964	0.0441	1.637	1.474
12	Eau Claire R. at Gordon	total rec.	13.43	0.0075	0.266	0.312	0.0379	1.552	0.220
		dissolved	2.80	0.0069	0.211	0.264	0.0136	0.837	0.198
13	Fish Creek (N) at highway 2	total rec.	NA	0.0090	2.370	1.420	0.2910	4.683	2.180
		dissolved	NA	0.0035	1.180	0.821	0.0099	2.763	0.344
14	Flambeau R. at Park Falls	total rec.	103.00	0.0108	NA	0.681	0.2760	3.345	0.865
		dissolved	20.30	0.0069	NA	0.542	0.1300	NA	0.371
15	Fox R. at Wrightstown	total rec.	91.00	0.0156	0.264	1.247	0.6098	5.654	3.453
		dissolved	14.09	0.0140	0.331	0.874	0.1210	1.782	1.792
16	Fox R. at Princeton	total rec.	289.00	0.0224	NA	0.669	0.9490	4.339	1.680
		dissolved	2.62	0.0070	NA	0.238	0.0660	NA	0.163
17	Fox R. (lower) at N. LLBDMorts	total rec.	309.00	0.0246	NA	1.340	1.4500	6.610	3.470
		dissolved	20.70	0.0057	NA	1.000	0.1170	NA	0.438
18	Grand R. (S. Fork) at Kingston	total rec.	183.51	0.0278	0.668	1.454	0.3239	5.347	4.214
		dissolved	5.46	0.0078	0.341	0.821	0.0312	3.445	1.109
19	Kickapoo R. at Oil City	total rec.	379.14	0.0253	0.836	1.093	0.9501	3.656	2.935
		dissolved	6.93	0.0042	0.233	0.511	0.0326	0.709	1.228
20	Kinnickinnic R. at Chase Ave.	total rec.	152.67	0.1565	7.092	9.156	5.8440	6.664	82.837
		dissolved	7.55	0.0710	2.244	5.202	0.3514	4.390	ND
21	Lincoln Creek at 47 St. Park	total rec.	129.84	0.0616	0.848	5.478	1.8502	4.823	16.120
		dissolved	16.31	0.0425	0.560	3.977	0.2522	1.570	10.606
22	Milwaukee R. at Batavia	total rec.	300.04	0.0206	0.496	1.263	0.6464	4.107	2.607
		dissolved	3.97	0.0063	0.191	0.779	0.0745	2.520	0.406
23	Milwaukee R. at Estebrook Park	total rec.	322.00	0.0442	0.933	1.771	1.9210	3.409	5.707
		dissolved	5.51	0.0071	0.253	1.285	0.2283	2.122	2.115
24	Mississippi R. at Alma	total rec.	515.00	0.0331	NA	1.860	0.8410	4.694	2.350
		dissolved	6.18	0.0125	NA	1.770	0.0910	NA	0.515
25	Mississippi R. at Diamond Bluff	total rec.	1620.0	0.0790	NA	2.510	1.8800	7.083	6.990
		dissolved	3.85	0.0247	NA	1.800	0.0970	NA	0.925
26	Mississippi R. at Trenton	total rec.	373.99	0.0510	0.908	2.069	1.0482	6.338	4.950

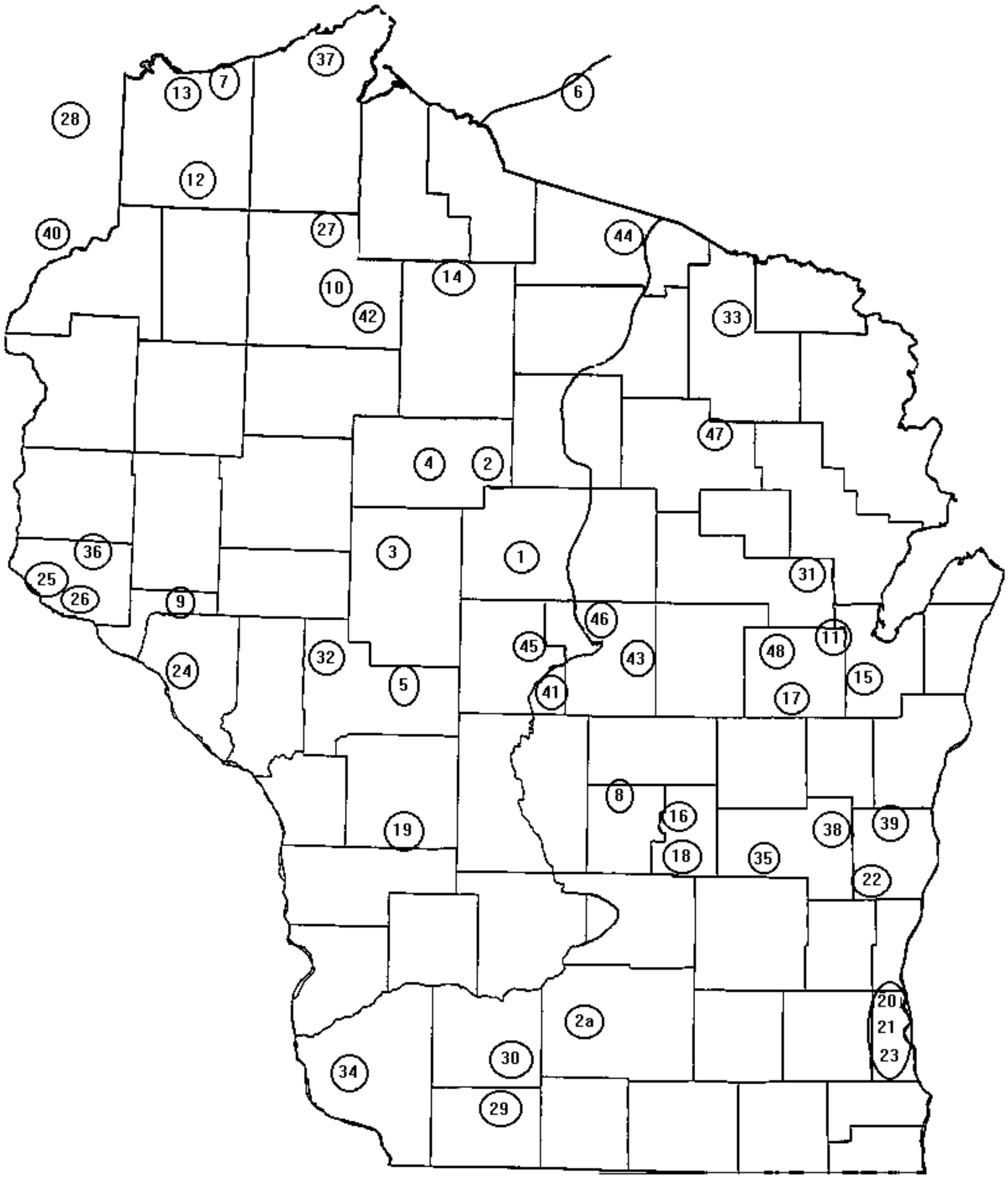
Surface Water Metals Data – Total Recoverable and Dissolved									
Site No.	Site Name		Al (µg/L)	Cd (µg/L)	Cr (µg/L)	Cu (µg/L)	Pb (µg/L)	Hg (ng/L)	Zn (µg/L)
		dissolved	4.30	0.0224	0.194	1.064	0.0711	0.656	1.168
27	Moose R. at Moose Lake	total rec.	158.09	0.0202	0.702	0.632	0.4622	8.724	3.335
		dissolved	112.88	0.0202	0.557	0.520	0.1970	7.830	2.929
28	Nemadji R. (MN) at Pleasant Valley	total rec.	641.17	0.0265	1.861	2.539	0.6623	5.362	4.335
		dissolved	13.85	0.0159	0.432	1.218	0.0450	3.794	0.496
29	Otter Creek at Darlington	total rec.	485.73	0.0307	0.768	1.409	1.7325	3.174	5.801
		dissolved	5.67	0.0065	0.132	0.729	0.0363	NA	0.731
30	Pecatonica R. (S.B.) at Hollandale	total rec.	614.41	0.0356	0.958	1.557	1.9702	3.799	5.065
		dissolved	4.58	0.0044	0.175	0.658	0.0369	1.370	0.466
31	Pensaukee R. (S.B.) at Krakow	total rec.	61.83	0.0117	0.388	1.193	0.1138	2.460	1.383
		dissolved	5.91	0.0070	0.293	0.918	0.0350	1.818	0.898
32	Pigeon Creek at York	total rec.	413.00	0.0384	0.678	1.130	0.5261	3.773	19.689
		dissolved	7.59	0.0104	0.163	0.640	0.0143	1.841	13.008
33	Popple R. at Popple River	total rec.	113.12	0.0214	0.462	0.455	0.4040	7.446	3.003
		dissolved	94.97	0.0153	0.422	0.506	0.2804	5.673	2.705
34	Rattlesnake Creek at Beetown	total rec.	300.26	0.0174	0.784	0.960	0.8144	4.244	3.152
		dissolved	3.50	0.0103	0.160	0.554	0.0430	NA	0.830
35	Rock R. at Waupun	total rec.	304.00	0.0165	NA	1.230	0.3720	4.741	1.900
		dissolved	4.52	0.0140	NA	1.061	0.0790	NA	0.616
36	Rush R. at Martell	total rec.	53.06	0.0115	0.295	0.598	0.0993	1.602	0.981
		dissolved	4.64	0.0081	0.252	0.466	0.0176	1.241	0.584
37	Sand R. at mouth (Hwy 13)	total rec.	807.77	0.0253	4.226	2.928	0.8476	4.654	4.313
		dissolved	26.56	0.0084	1.294	1.071	0.0174	2.831	0.335
38	Sheboygan R. at Dotyville	total rec.	116.00	0.0056	0.310	0.827	0.3170	1.240	1.180
		dissolved	3.31	0.0048	0.127	0.573	0.0391	0.750	0.411
39	Sheboygan at Sheboygan Marsh	total rec.	19.32	0.0084	0.818	0.344	0.1183	2.166	0.555
		dissolved	2.51	0.0053	0.185	0.108	0.0520	1.927	0.339
40	Tamarack R. (MN) at Cloverton	total rec.	101.05	0.0105	0.511	0.958	0.1730	5.544	1.976
		dissolved	54.10	0.0078	0.458	0.872	0.1080	4.669	1.587
41	Ten Mile Creek at Nekoosa	total rec.	126.94	0.0122	1.190	1.069	0.1145	5.862	0.954
		dissolved	6.54	0.0098	0.752	0.747	0.0098	2.111	0.302
42	Thornapple R. at Dairy Center	total rec.	145.98	0.0190	0.552	0.773	0.1735	5.841	2.167
		dissolved	59.14	0.0123	0.436	0.682	0.1056	5.187	1.801
43	Tomorrow R. at Nelsonville	total rec.	39.48	0.0064	0.573	0.339	0.0934	2.573	1.001
		dissolved	17.55	0.0061	0.550	0.268	0.0428	2.260	0.722
44	Wisconsin at Conover	total rec.	23.54	0.0056	0.265	0.268	0.1681	1.731	0.603
		dissolved	8.43	0.0047	0.215	0.179	0.0808	1.165	0.395
45	Wisconsin R. at Biron	total rec.	228	0.0183	NA	1.230	0.6260	4.718	2.060
		dissolved	18.30	0.0085	NA	1.160	0.2460	NA	0.892

Surface Water Metals Data – Total Recoverable and Dissolved									
Site No.	Site Name		Al (µg/L)	Cd (µg/L)	Cr (µg/L)	Cu (µg/L)	Pb (µg/L)	Hg (ng/L)	Zn (µg/L)
46	Wisconsin R. at Plover	total rec.	204.33	0.0248	0.569	1.338	0.4654	5.207	3.120
		dissolved	41.04	0.0097	0.381	0.906	0.1194	3.725	1.651
47	Wolf R. at Lily	total rec.	46.34	0.0094	0.603	0.376	0.2020	2.481	0.959
		dissolved	11.02	0.0054	0.315	0.313	0.1040	1.724	0.371
	Wolf R. at Shiocton	total rec.	NA	0.0108	NA	0.460	NA	2.400	1.050
		dissolved	6.59	0.0060	0.459	0.358	0.0635	1.550	0.510
	Lake Michigan at 7 mi. off Milw.	total rec.	5.95	0.0085	0.49	0.44	0.052	NA	0.39
		dissolved	0.73	0.0053	0.47	0.38	0.0078	NA	0.26

Summary of detection criteria:

	Detection Limit	Sample Precision[1]
Aluminum (µg/L)	0.170	0.104
Cadmium (µg/L)	0.0044	0.0015
Copper (µg/L)	0.039	0.017
Chromium (µg/L)	0.001	0.0004
Lead (µg/L)	0.048	0.021
Mercury (ng/L)	0.5	0.1
Zinc (µg/L)	0.028	0.015

1. Mean precision (+/- 1 standard deviation) of samples



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Appendix D: Expression of Limits Examples

Municipal Discharger Examples:

Limitations shall be expressed as both a weekly average and a monthly average (s. NR 106.07(3)(e))

Example 1: Reasonable potential shows need to only include a daily maximum limit

Calculated Copper WQBELs:

Daily Max = 99 µg/L

Weekly Avg. = 14,142 µg/L

Monthly Avg. = N/A

Copper 1-day P_{99} = 104 µg/L

Daily Maximum Limit Based on Reasonable Potential

Effective Permit Limits:

Weekly and monthly average permit limits needed – Limits would be set equal to the daily maximum

Daily Max = 99 µg/L and a daily mass limit

Weekly Avg. = 99 µg/L *This limit is more restrictive than the calculated WQBEL of 14,142 µg/L*

Monthly Avg. = 99 µg/L

Mass limits are only required for the averaging period where reasonable potential is demonstrated.

Example 2: Reasonable potential for daily and monthly average limit

Calculated Ammonia-nitrogen WQBELs:

Daily Max = 12 mg/L	Effluent 1-day P_{99} = 14 mg/L
Weekly Average = 14 mg/L	Effluent 4-day P_{99} = 12 mg/L
Monthly Average = 5.6 mg/L	Effluent 30-day P_{99} = 11 mg/L

Daily Maximum and Monthly Average Limits needed based on reasonable potential. Weekly average limit still needed for expression of limits. There are three possible weekly average limits:

- *Weekly average limit based on daily max WQBEL*
- *Weekly average limit based on monthly average WQBEL*
- *Weekly average WQBEL*

The most restrictive of these three should be included in the permit.

Weekly average limit based on daily max WQBEL:

The weekly average limit would be set equal to the daily max WQBEL

= **12 mg/L**

Weekly average limit based on monthly average WQBEL: *Calculated using Table 8* (from s. NR 106.07(3)(e)4, Wis. Adm. Code)

$$Weekly\ Average\ Limit = Monthly\ Average\ Limit \times MF$$

Where:

MF= Multiplication Factor as defined in Table 8 using CV and n

CV= Coefficient of variation (CV) as calculated in s. NR 106.07(5m)

n= the number of samples per month required in the permit

$$CV = \frac{standard\ deviation}{arithmetic\ mean}$$

CV = 2.11 ÷ 10 = 0.21

For sampling 3x week, n = 12

MF = 1.36 (from Table 8)

Weekly average permit limit = 5.6 mg/L × 1.36

= **7.6 mg/L**

This limit is more restrictive than the other possible limits of 12 mg/L and the WQBEL of 14 mg/L. Therefore, the weekly average limit should be 7.6 mg/L.

Effective Permit limits:

Daily Max = 12 mg/L

Weekly Average = 7.6 mg/L

Monthly Average = 5.6 mg/L

No mass limits are needed for ammonia-nitrogen based on s. NR 106.32(5)(b), Wis. Adm. Code.

Because ammonia-nitrogen limits are usually calculated seasonally, this evaluation will be necessary for each separate season.

Industrial Discharger Examples:

Limitations shall be expressed as both a daily maximum and a monthly average (s. NR 106.07(4)(e))

Example 3: Reasonable potential shows need to only include a weekly average limit

Calculated Chloride Limits:

Daily Max= 757 mg/L

Weekly Avg. = 400 mg/L

Monthly Avg. = N/A

Weekly Average Limit Based on Reasonable Potential

Daily maximum and monthly average permit limits needed.

The monthly average limit is simply set equal to the weekly average limit.

For the daily maximum limit, use Table 9 (from s. NR 106.07(4)(e), Wis. Adm. Code):

$$Daily\ Maximum\ Limit = Weekly\ Average\ Limit \times DMF$$

Where:

DMF = Daily Multiplication Factor based on CV as defined in Table 9 based on the CV

CV= Coefficient of variation (CV) as calculated in s. NR 106.07(5m)

$$CV = \frac{standard\ deviation}{arithmetic\ mean}$$

CV = 64.2 ÷ 293 = 0.2

DMF = 1.235 (from Table 9)

Daily Maximum Limitation = 400 mg/L × 1.235 = 494 mg/L *This is more restrictive than the daily max WQBEL of 757 mg/L.*

Effective Permit limits:

Daily maximum = 494 mg/L

Weekly average = 400 mg/L and a weekly average mass limit

Monthly average = 400 mg/L

Example 4: Reasonable potential shows need to only include a monthly average limit

Calculated Mercury WQBELs:

Daily Max = 830 ng/L

Weekly Avg. = 440 ng/L

Monthly Avg. = 1.3 ng/L

Mercury 30-day P_{99} = 1.5 ng/L

Monthly Average Limit Based on Reasonable Potential

Daily permit limit needed: Use Multiplication Factor from Table 8

$$Daily\ Maximum\ Limit = Monthly\ Average\ Limit \times MF$$

Where:

MF= Multiplication factor as defined in Table 8

CV= Coefficient of variation (CV) as calculated in s. NR 106.07(5m)

n= Number of samples per month required in the permit

$$CV = \frac{standard\ deviation}{arithmetic\ mean}$$

CV = 0.24 ÷ 0.76 = 0.31

For a monthly monitoring frequency, n = 1

MF = 1.0 (from Table 8)

Daily maximum permit limit = 1.3 ng/L × 1.0 = 1.3 ng/L

This limit is more restrictive than the calculated WQBEL of 830 ng/L

Effective Permit Limits:

Daily Max = 1.3 ng/L

Monthly average = 1.3 ng/L and a monthly average mass limit

Appendix E: Significant Figures

The following policies are generally recommended for handling the significant figures on monitoring data, input parameters, and the resulting limits.

- Effluent monitoring and water quality data should be listed with the same number of significant figures with which it was reported. Generally effluent monitoring data will be reported with 2-3 significant figures. Data with four or more significant figures require extremely accurate analytical methods and some general explanation for the accuracy should be available.
- Results of calculations using monitoring data (average, P_{99}, etc.) should be reported using the same number of significant figures as the reported monitoring data.
- For the purposes of limit calculating, water quality criteria should not affect the significant figures of the calculation results.
- **For consistency, effluent limits to be included in permits should be rounded to two significant figures** at the end of limit calculations. This is the same number of significant figures that stream flows and “f” factors are most commonly reported in. Exceptions to this include:
    - The IWC for WET limits, which should be rounded to a whole percentage
    - Some types of categorical limits
    - TMDL limits – use the same number of significant figures as the WLA
- In any limit calculations with multiple steps, intermediate answers should not be rounded; only round to the correct number of significant figures for the final answer. Mass limits should be calculated based upon the original effluent limitation, prior to rounding, and be rounded to two significant figures at the end of the calculation.
- Where limits in current permits include more than two significant figures, limits should not be rounded at reissuance to avoid artificially raising or lowering effluent limits.

Appendix F: Serial Correlation

The procedures for calculating a P_{99} laid out in s. NR 106.05(5)(a), Wis. Adm. Code, are predicated on the fact that the data are not serially correlated. Effluent data sets can be adjusted if its demonstrated that the data is serially correlated. Section NR 106.05(5)(b), Wis. Adm. Code, states:

> *When the daily discharge concentrations of any substance are serially correlated, the serially correlated data may be adjusted using appropriate methods such as that presented in Appendix E of "Technical Support Document for Water Quality–based Toxics Control", U.S. environmental protection agency, March 1991 (EPA/505/2–90–001).*

The code goes on to state that the P_{99} calculation may be adjusted for serial correlation accordingly.

When effluent data is collected with a relatively short sample interval, consecutive results may be correlated with each other, meaning that the calculated P_{99} values would underestimate the actual long-term effluent variability. The technical support document states that effluent data are more likely to be serially correlated in situations where the time between effluent sampling events is much shorter than the hydraulic retention time of the treatment system. This is a good assumption to apply to conservative toxic pollutants, since effluent variability is largely influenced by the influent pollutant levels. However, other pollutants such as ammonia-nitrogen may be more dependent on the treatment process than influent concentrations. These types of pollutants are more likely to be serially correlated than other pollutants, even in systems with a short hydraulic retention time.

Ideally, scenarios where effluent data are serially correlated should be avoided by selecting an appropriate effluent monitoring frequency, considering the hydraulic retention time and the expected variability of the parameter. For example, when a permittee performs additional metals monitoring in order to achieve 11 sample results, department staff typically recommend monitoring at least 3 days apart to avoid the need to adjust the dataset for serial correlation. Monitoring performed at too close of a frequency causes some of the monitoring results to be effectively redundant with others, not capturing possible effluent variability, which ultimately wastes time and resources acquiring unneeded data. However, parameters like temperature and pH are known to vary more frequently in some discharges, so daily or continuous monitoring for these parameters is not necessarily inappropriate.

There are statistical tests that can be used to determine if a data set is serially correlated. But most often, it should be visually apparent if the data set is serially correlated upon graphing the data. The question to answer is, "Does a deviation from the expected in a result on one day predict a deviation from the expected result on the next day?". The "expected" will be different depending on the parameter. For a parameter with no seasonal trend, the expected will be the mean. If a data set is not serially correlated at all, each result should appear mostly random compared to the days before it and after it. For a parameter that does vary seasonally though, the expected value varies throughout the year based on some equation. The data is serially correlated if an excursion from that expected trend predicts an excursion the next day.

The effluent data used in P_{99} calculations can be adjusted to account for serial correlation using the procedures in Appendix E of the 1985 *EPA Technical Support Document for Water Quality-Based Toxics Control*. These procedures explain how to adjust the variable, n, which is the number of discharge concentrations used to calculate an average over a specified monitoring period. Without an adjustment for serial correlation, n=1 for daily concentrations, 4 for 4−day averages and 30 for 30−day averages.

The calculated n_e calculated from the equation below can be substituted into the equation for calculating the P_{99}. The meaning of n_e is an equivalent concentration count due to the serial correlation.

In order to perform this calculation, the dataset should have a consistent sample interval. This type of monitoring is uncommon, except where daily monitoring is required. For most permittees, the intervals between sample days is not constant.

The first step is to determine P, the "lag-1 correlation," which is a relative indicator of serial correlation by factoring in the results of the subsequent sample in a series of calculations. The variable P can range from -1 to +1, but $P < 0$ is rare. P=1 indicates maximum serial correlation. If P=0, it may be assumed the results are independent or uncorrelated. The value P will be negative if consecutive results regularly alternate above and below the calculated mean.

For a dataset without a seasonal trend, the lag-1 correlation is calculated using results from each day and the results from the subsequent day. The formula for calculating P is as follows:

$$P = \frac{\sum_{i=1}^{k-1}(X_i - X_m)(X_{i+1} - X_m)}{\sum_{i=1}^{k}(X_i - X_m)^2}$$

Where:

x_i	= the effluent concentration on day i,
x_{i+1}	= the effluent concentration on day i+1 (the next sample day), and
x_m	= the mean of the entire sample database.
P	= lag-1 correlation

If the lag-1 correlation is greater than zero it may be appropriate to adjust the 4-day and 30-day P_{99} calculations. When adjusting for serial correlation, the adjustment has some impact on the 4-day P_{99}, but even greater impact on the calculation of the 30-day P_{99}. The lag-1 correlation can be used to calculate an adjusted n value of the 4 or 30 day P_{99} calculations using this equation:

$$n_e = \frac{n^2(1 - P^T)^2}{n(1 - P^{2T}) - 2P^T(1 - P^{nT})}$$

n	= the "intended sample size" (1, 4, or 30 for the respective P_{99})
n_e	= sample size adjusted for serial correlation
T	= sample frequency

This would need to be calculated differently for a dataset with a seasonal trend such as temperature or ammonia-nitrogen. For a dataset with seasonal variability, the variance would be calculated as variance from an equation describing the seasonal trend instead of a variance from the mean of the dataset.

Example:

Day Number	X_i	X_{i+1}	$X_i - X_m$	$X_{i+1} - X_m$	$(X_i - X_m)^2$	$(X_i - X_m)(X_{i+1} - X_m)$
1	0	0	-3	-3	9	9
2	0	2	-3	-1	9	3
3	2	5	-1	2	1	-2
4	5	5	2	2	4	4
5	5	3	2	0	4	0
6	3	2	0	-1	0	0
7	2	4	-1	1	1	-1
8	4	10	1	7	1	7
9	10	8	7	5	49	35
10	8	0	5	-3	25	-15
11	0	0	-3	-3	9	9
12	0	1	-3	-2	9	6
13	1	1	-2	-2	4	4
14	1	3	-2	0	4	0
15	3	0	0	-3	0	0
16	0	0	-3	-3	9	9
17	0	3	-3	0	9	0
18	3	9	0	6	0	0
19	9	4	6	1	36	6
20	4			SUM	183	74

Mean, $X_m = 3$
$T = 1$ (For daily monitoring)

$$P = \frac{74}{183} = 0.404$$

To adjust n for the P_{99} calculation use the formula:

$$n_e = \frac{n^2(1-P^T)^2}{n(1-P^{2T}) - 2P^T(1-P^{nT})}$$

For a 4-day P_{99} calculation:

$$n_e = \frac{4^2(1 - 0.404^1)^2}{4(1 - 0.404^{2\times1}) - 2 \times 0.404^1(1 - 0.404^{4\times1})} = 3.99$$

For a 30-day P_{99} calculation:

$$n_e = \frac{30^2(1 - 0.404^1)^2}{30(1 - 0.404^{2\times1}) - 2 \times 0.404^1(1 - 0.404^{30\times1})} = 13.16$$

The P_{99} calculations can be adjusted for serial correlation by substituting 3.99 for 4 in the 4-day P_{99} calculation and 13.16 for 30 in the 30-day P_{99} calculation. This adjustment only significantly impacts the 30-day P_{99} calculation. This effectively reduces the calculation from a 30-day average to a 13-day average, which results in a higher P_{99} value. To summarize, the following table shows the impact of adjustment for serial correlation on the P_{99} values for the example dataset.

		Original P_{99}, Not-adjusted	Serial Correlation Adjusted Value
4-day P_{99}			
	n	4	3.99
	P_{99}	8.19	8.20
30-day P_{99}			
	n	30	13.16
	P_{99}	4.56	5.53